

Measurement of the Top Cross Section at CDF

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Joint Experimental and Theoretical Seminar
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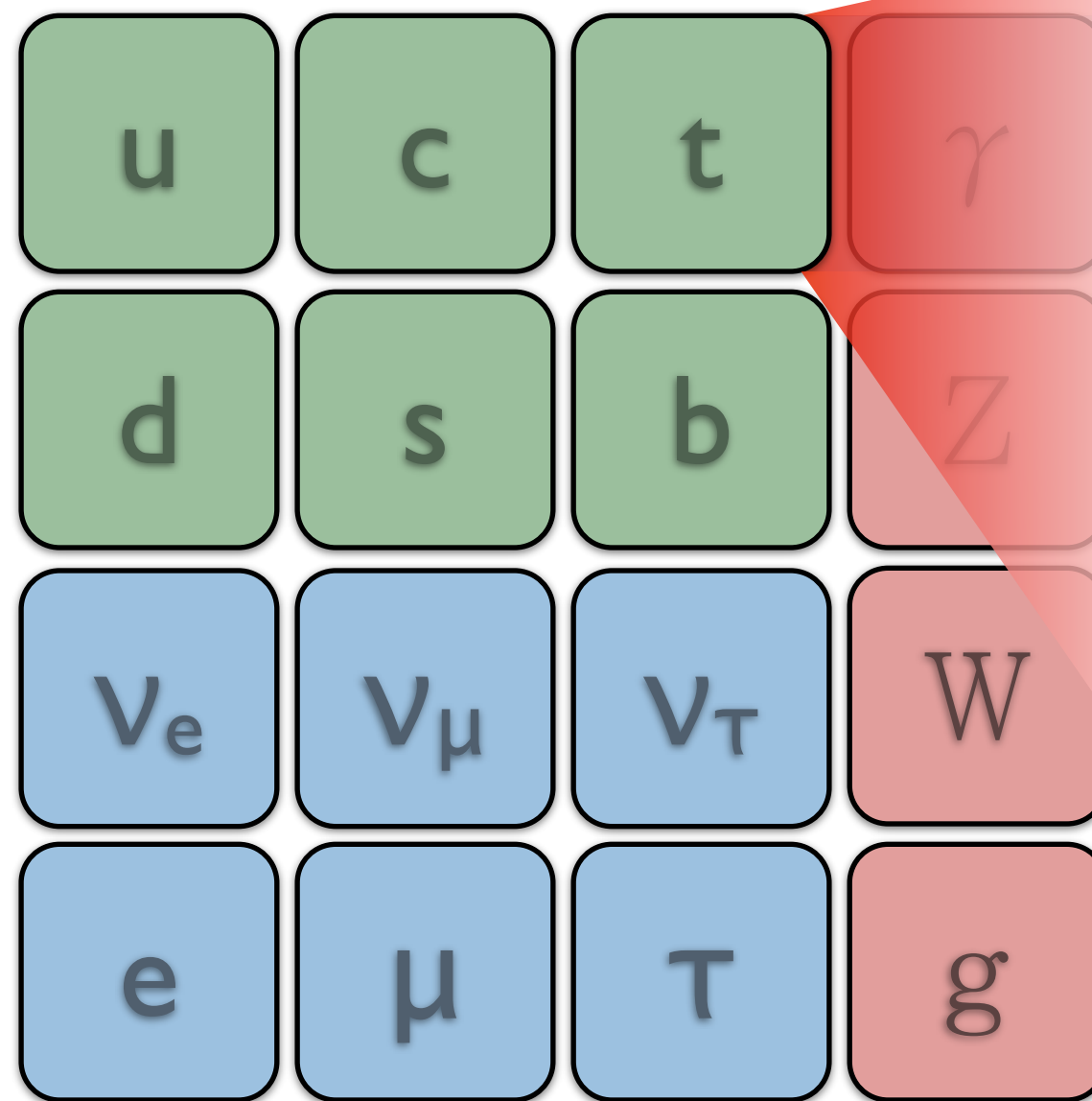
The Standard Model

Top Quark

u	c	t	γ
d	s	b	Z
ν_e	ν_μ	ν_τ	W
e	μ	τ	g

The Standard Model

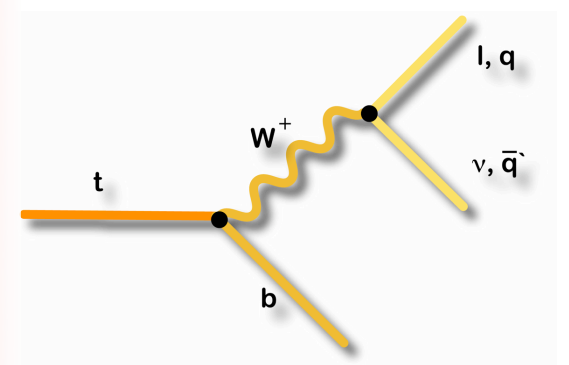
Top Quark



spin 1/2

charge +2/3

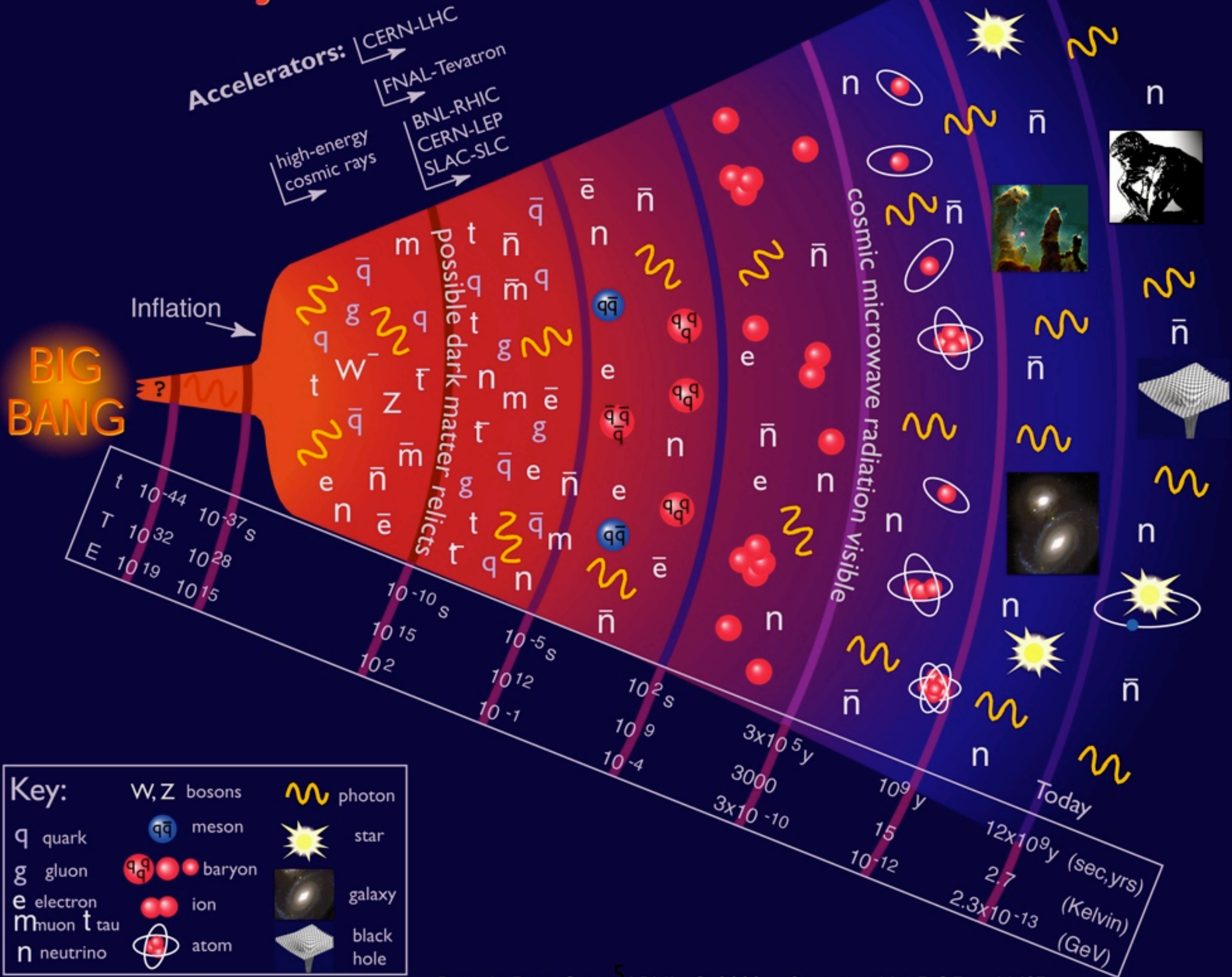
$$\begin{pmatrix} t \\ b \end{pmatrix}_L \quad t_R$$



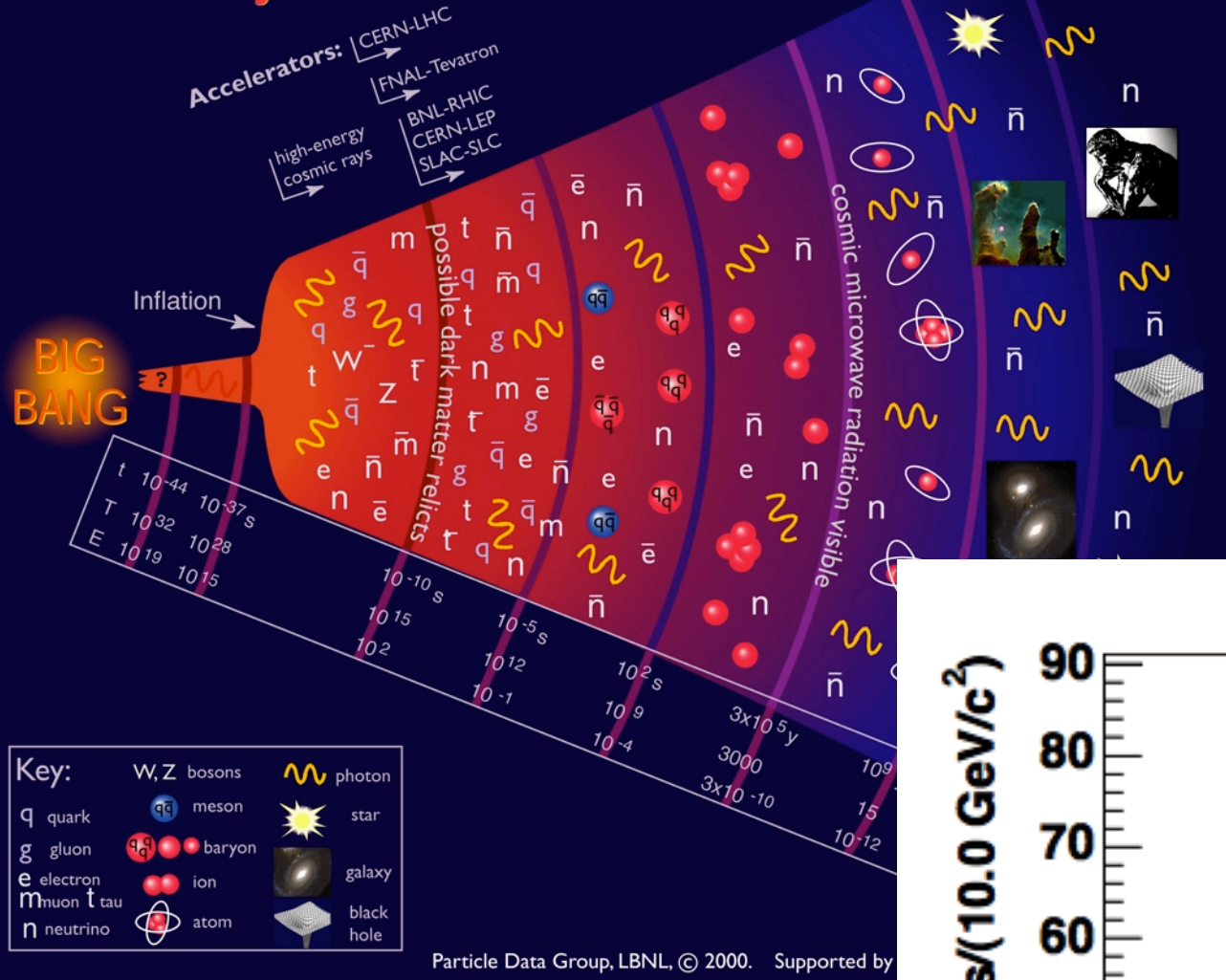
up
3 MeV

•

History of the Universe

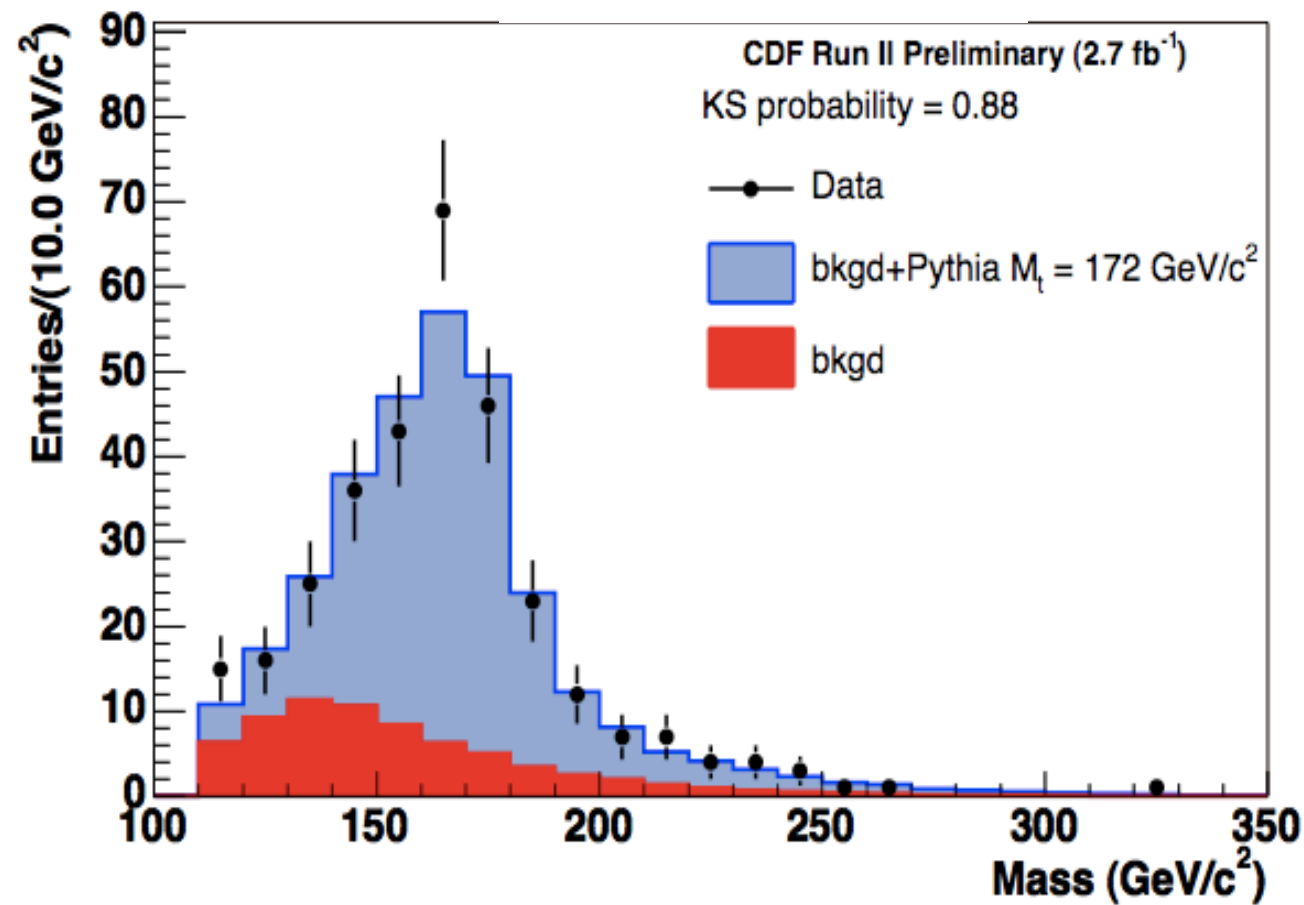


History of the Universe



CDF Run II

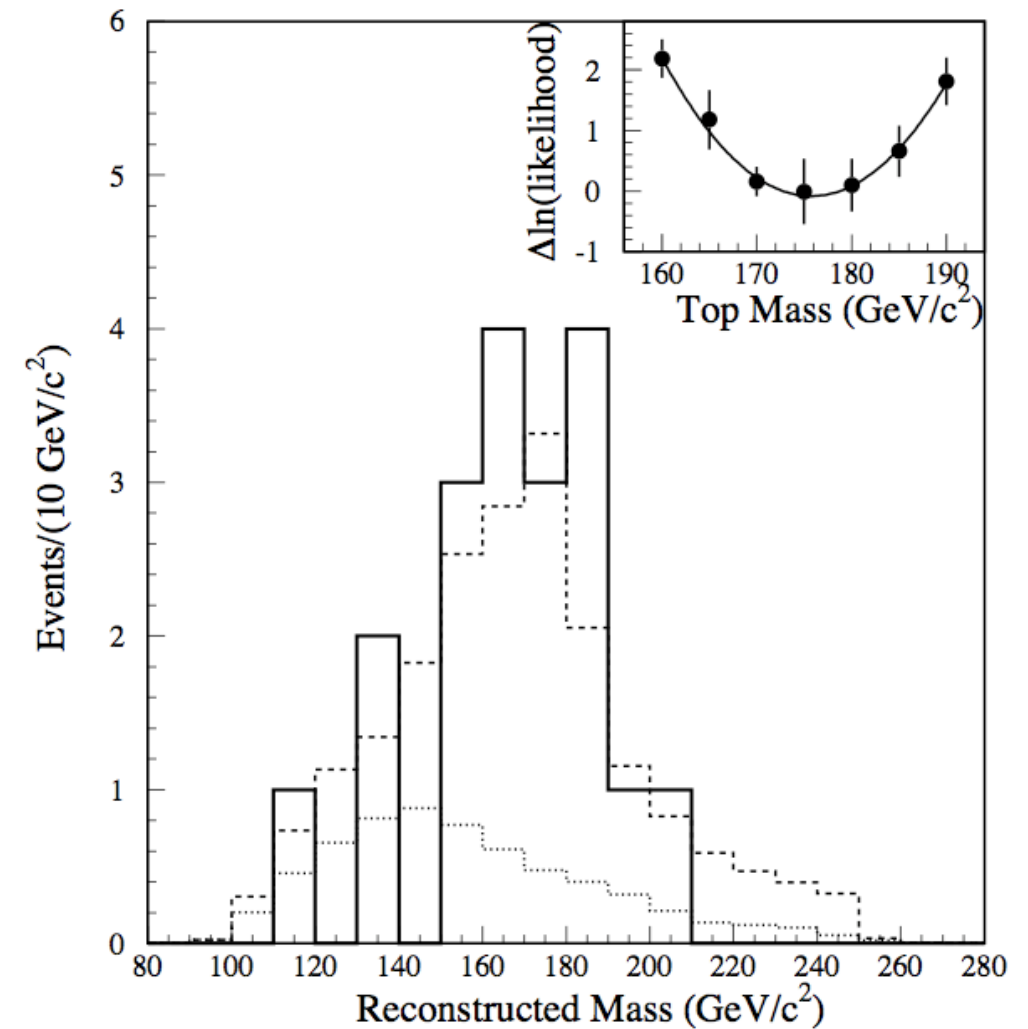
2.7 fb^{-1}



$$M_t = 172.3 \pm 1.9 \text{ GeV}/c^2$$

Run I Observation

67 pb^{-1}



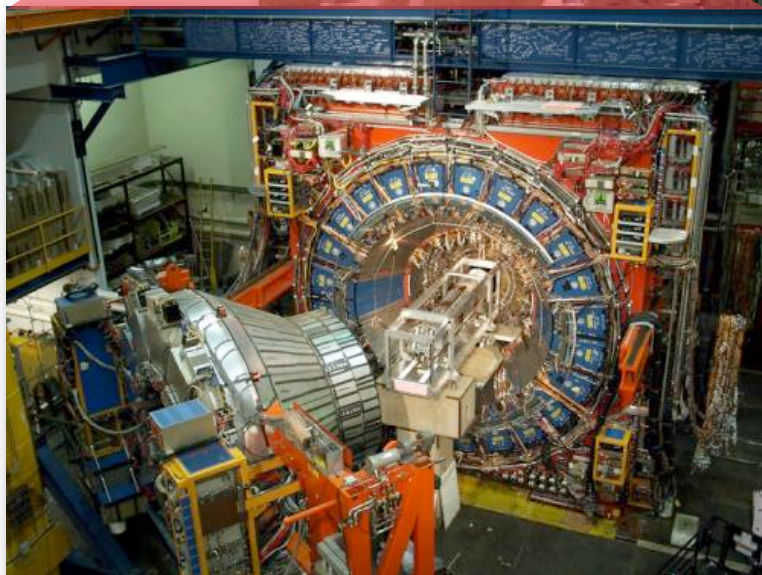
$$M_t = 176 \pm 12.8 \text{ GeV}/c^2$$

The Tevatron

Colliding protons and anti-protons at 1.96 TeV



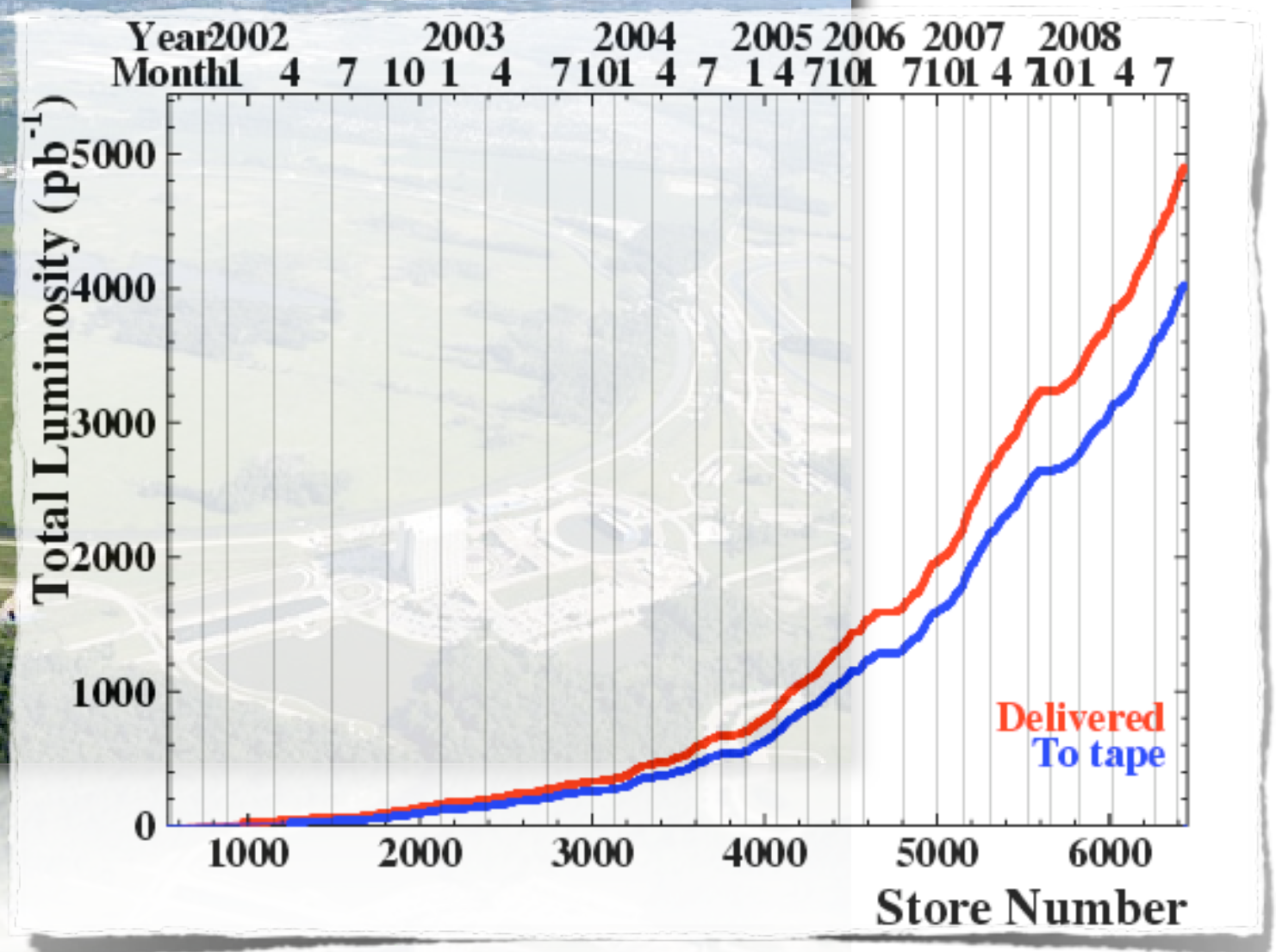
CDF



The Tevatron

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CDF

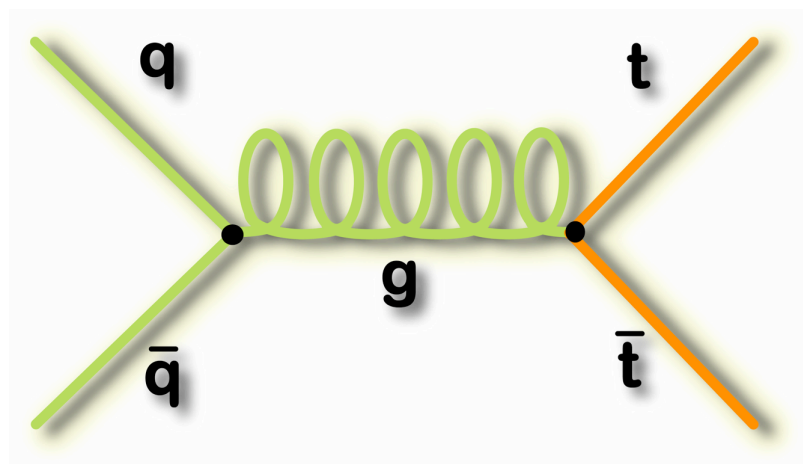


$\sim 5 \text{ fb}^{-1}$ delivered

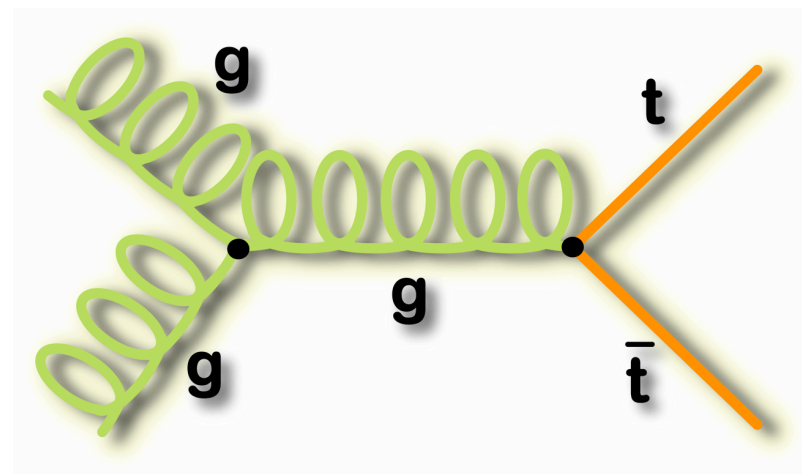
$\sim 3 \text{ fb}^{-1}$ in current analysis

How is Top Produced?

Mostly through the Strong Force



85 %

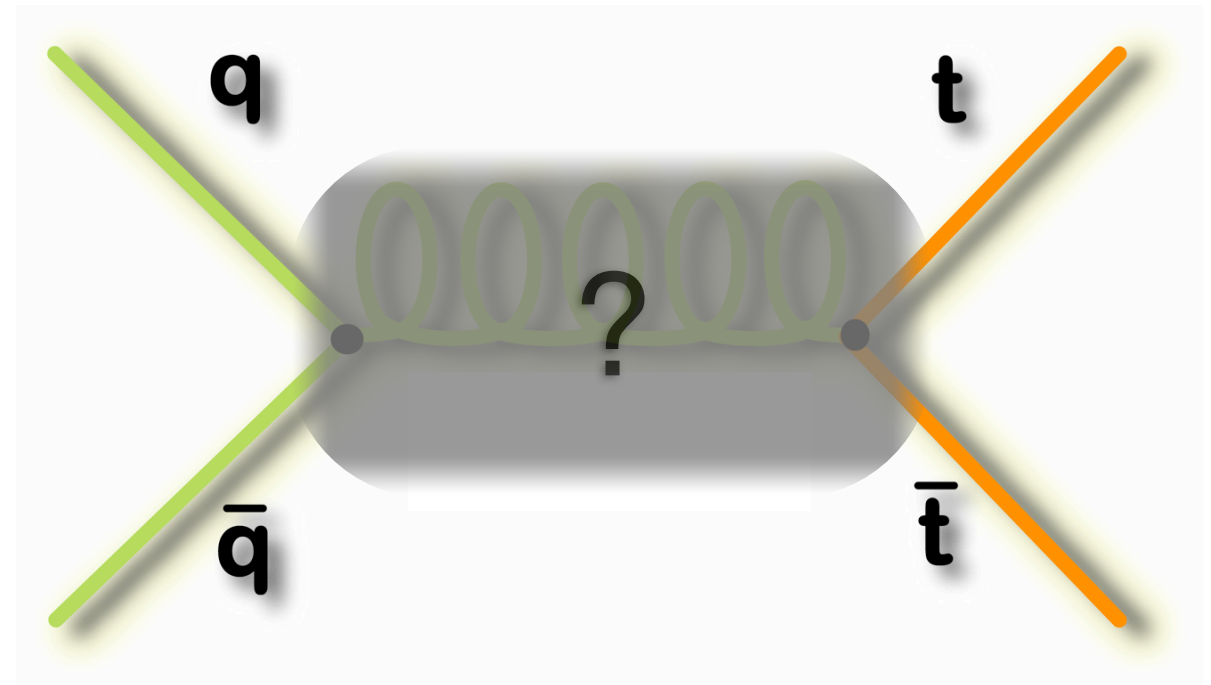


15 %

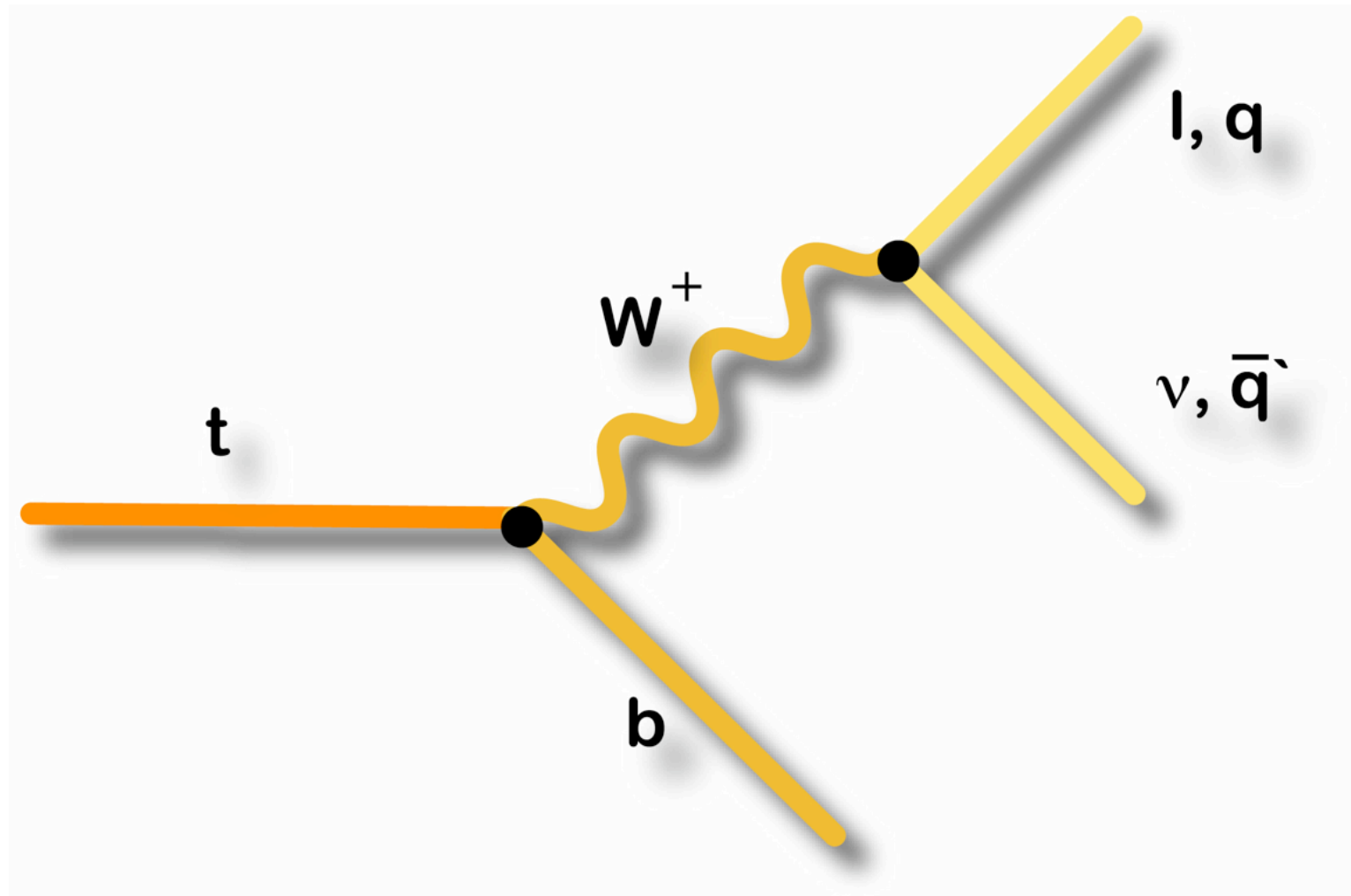
Takes ~ 350 GeV to make a pair of top quarks

or Maybe there's more....

- New production mechanisms would most likely show up as an enhancement in the cross section
- Kaluza-Klein excitations of gluons from extra dimensional theories
- New gauge boson as a remnant of some higher order symmetry breaking, such as Z'

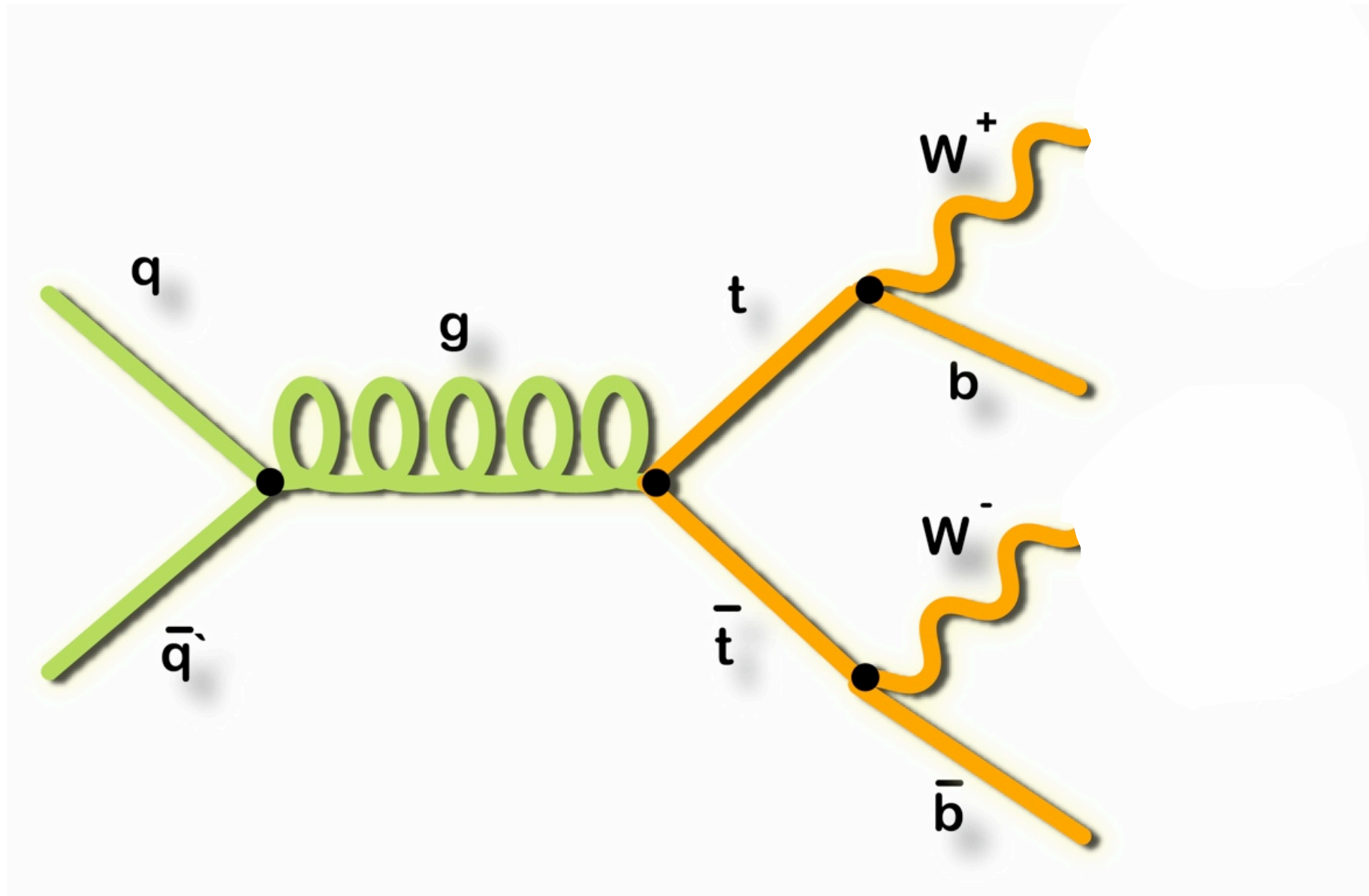


How Does Top Decay?

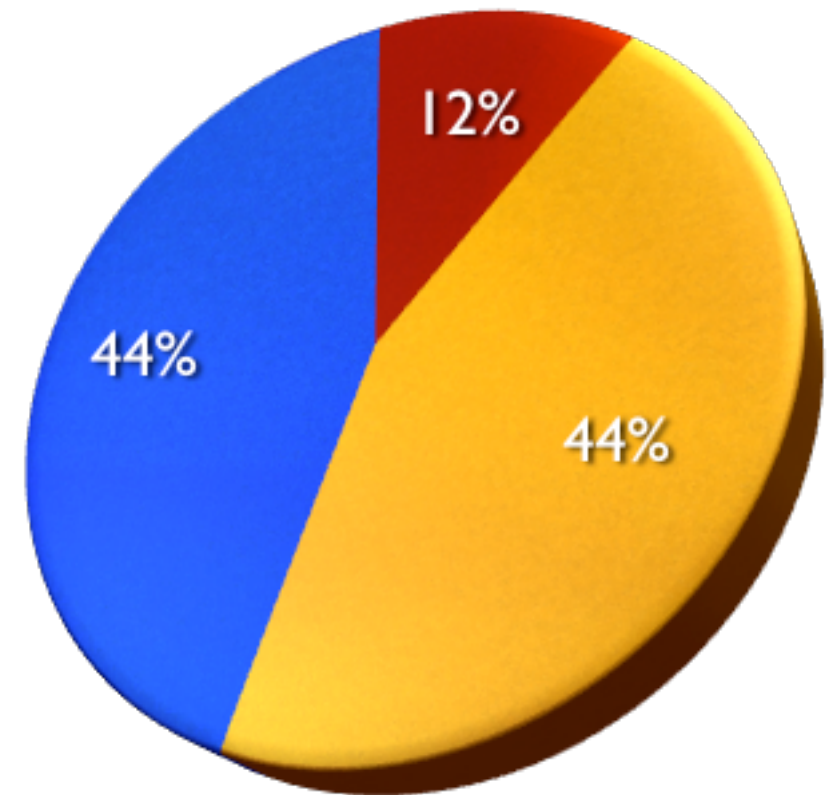
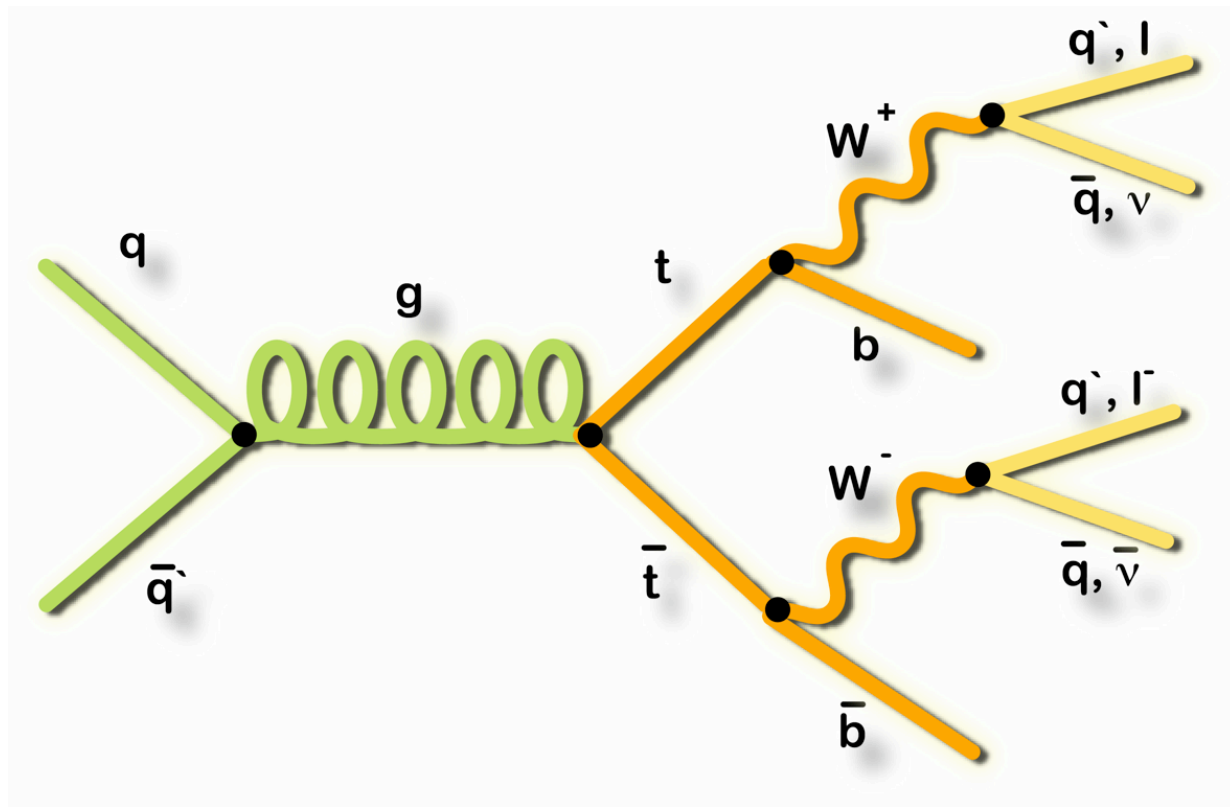


$\sim 100\%$

Top Events Are Defined By How The W's Decay

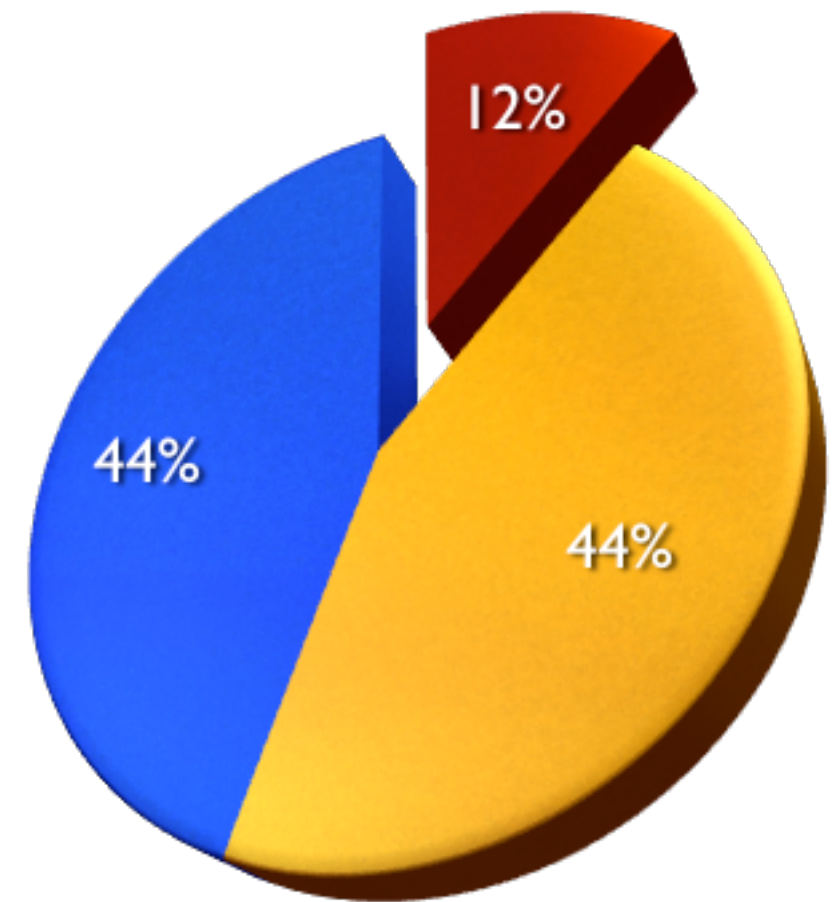
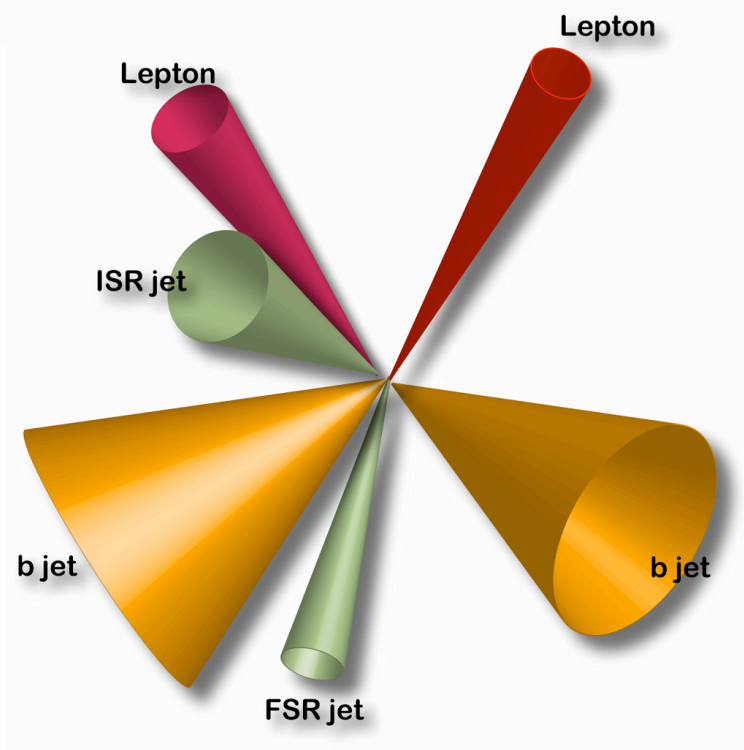
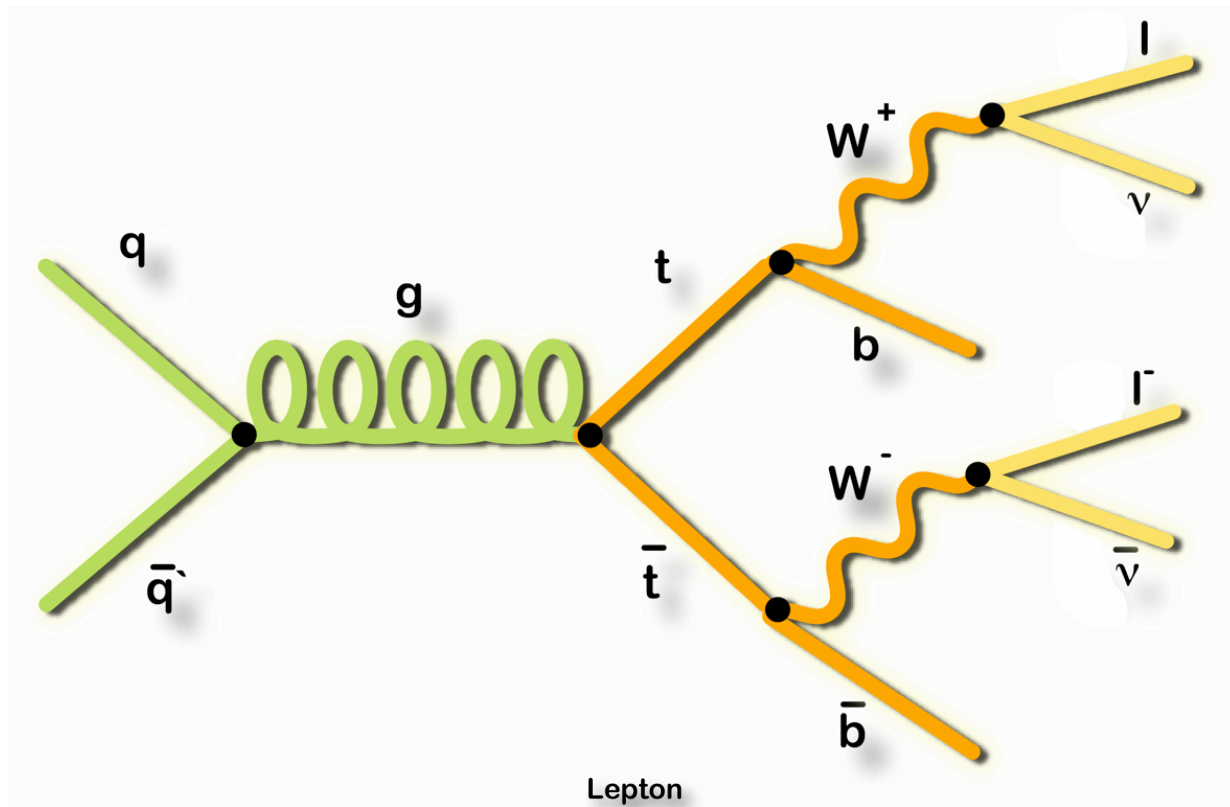


Top Decay Channels



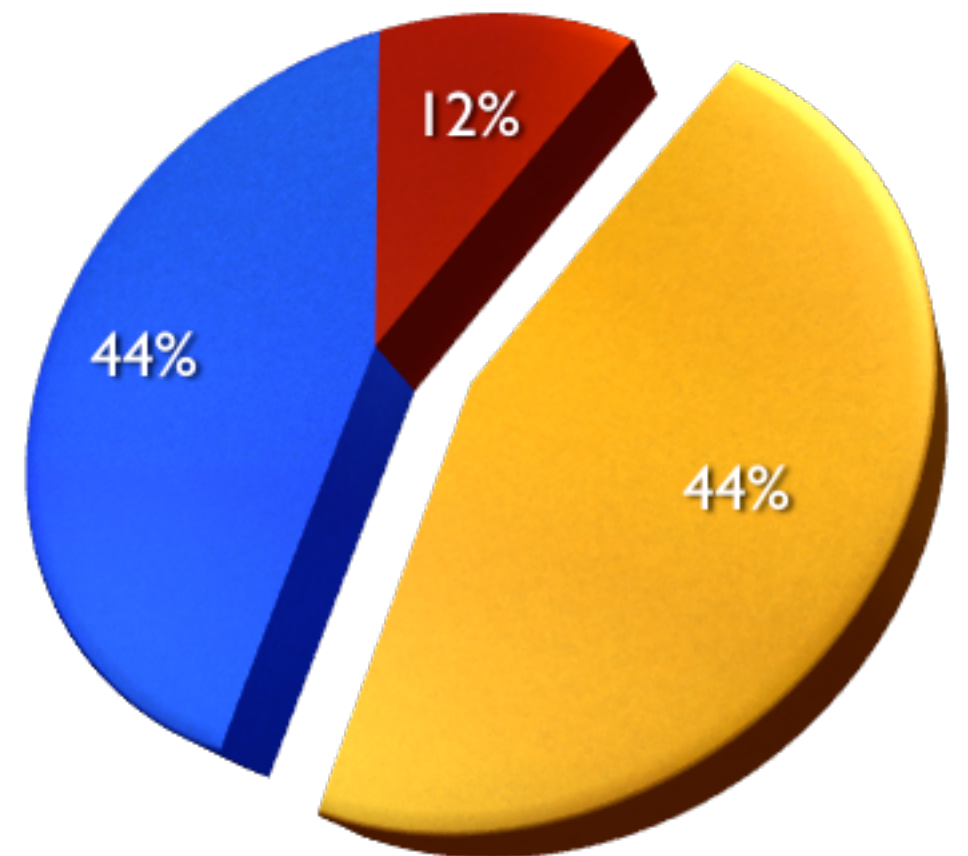
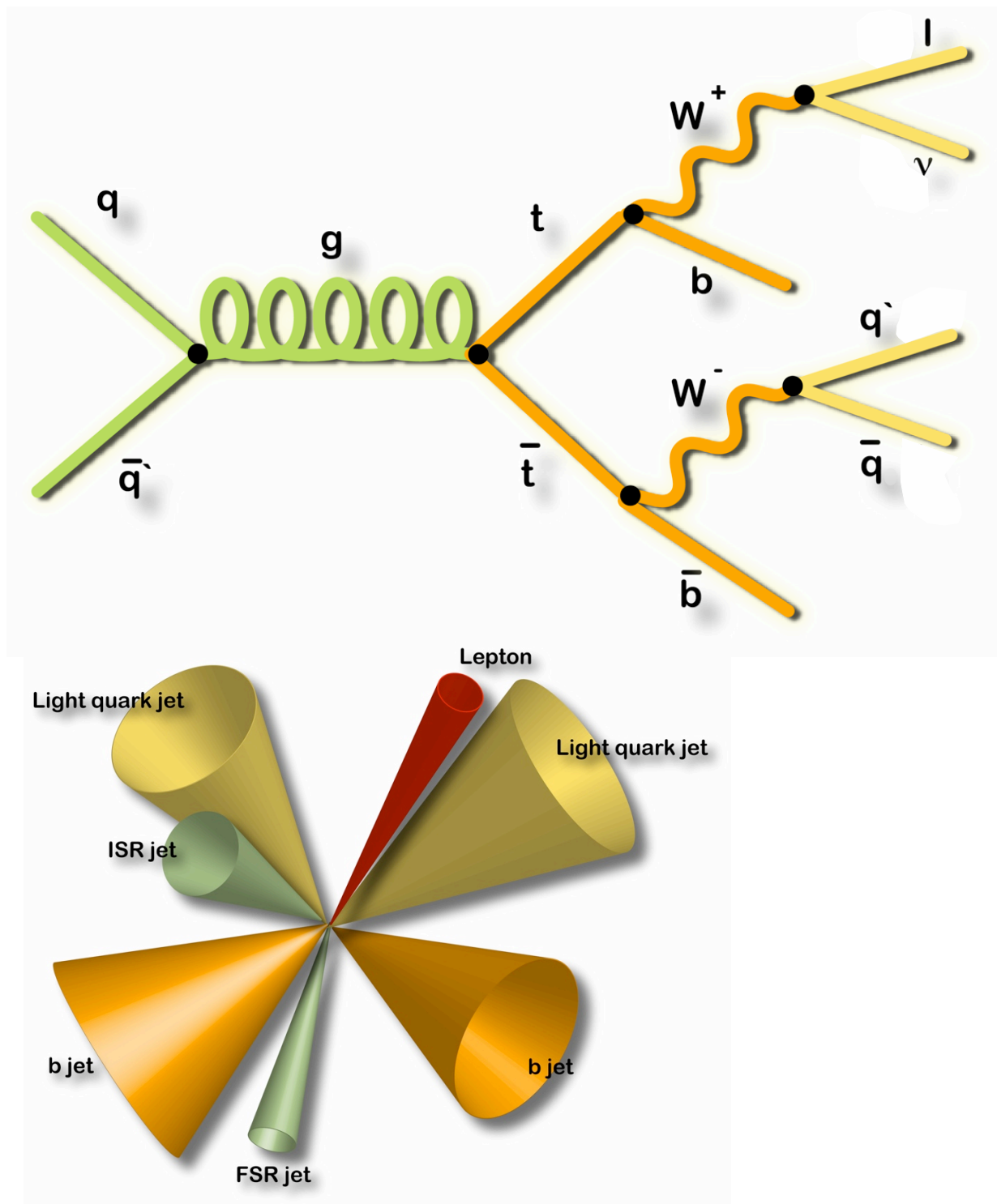
- Di-lepton ($W \rightarrow l\nu$ $W \rightarrow l\nu$)
- Lepton + Jets ($W \rightarrow l\nu$ $W \rightarrow qq$)
- All-hadronic ($W \rightarrow qq$ $W \rightarrow qq$)

Di-lepton Channel



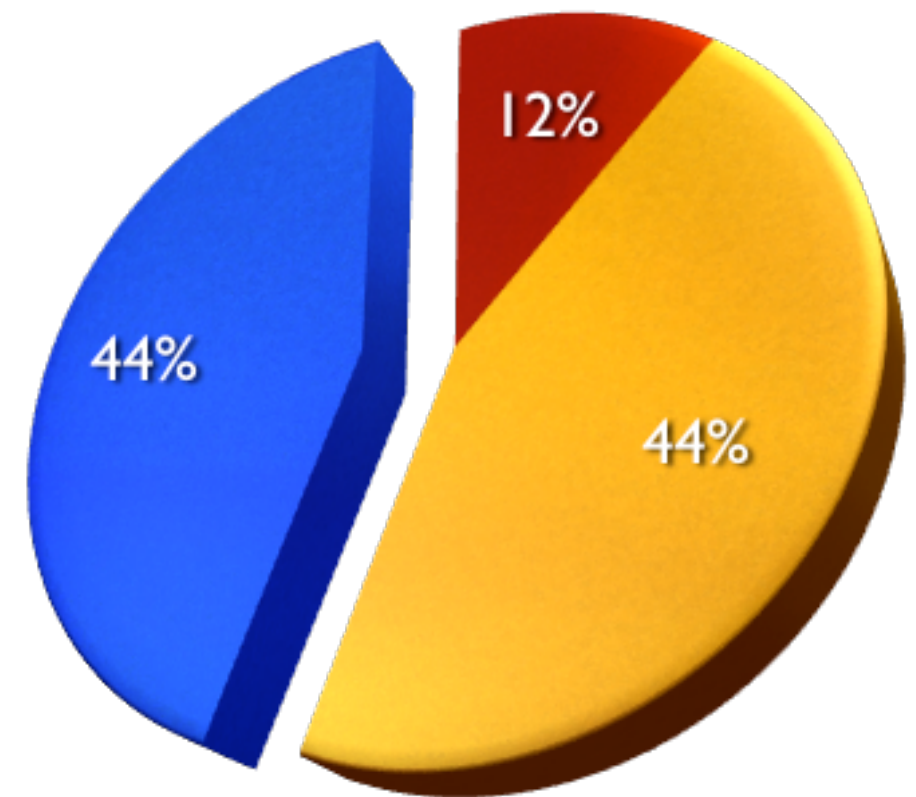
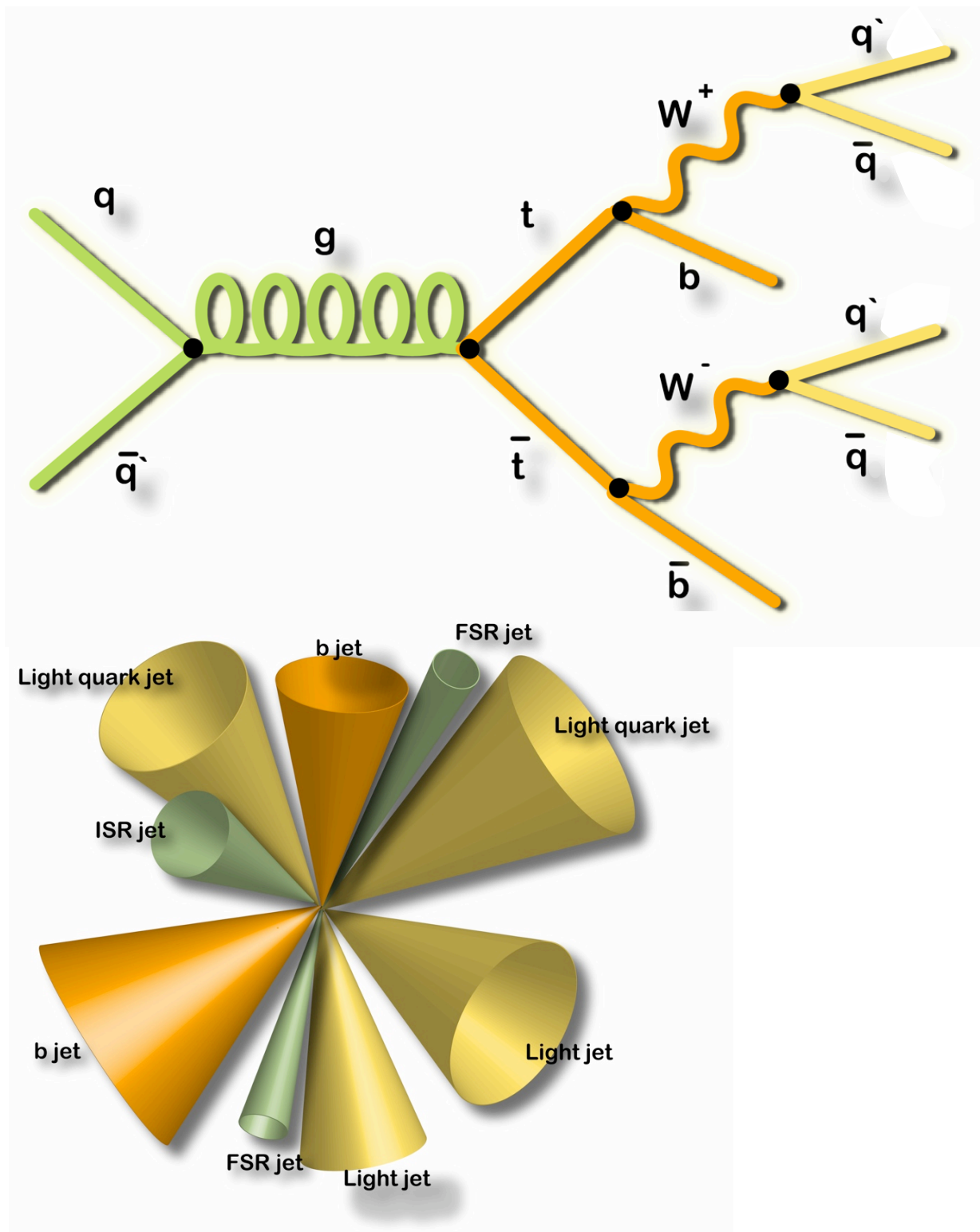
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Lepton + Jets Channel



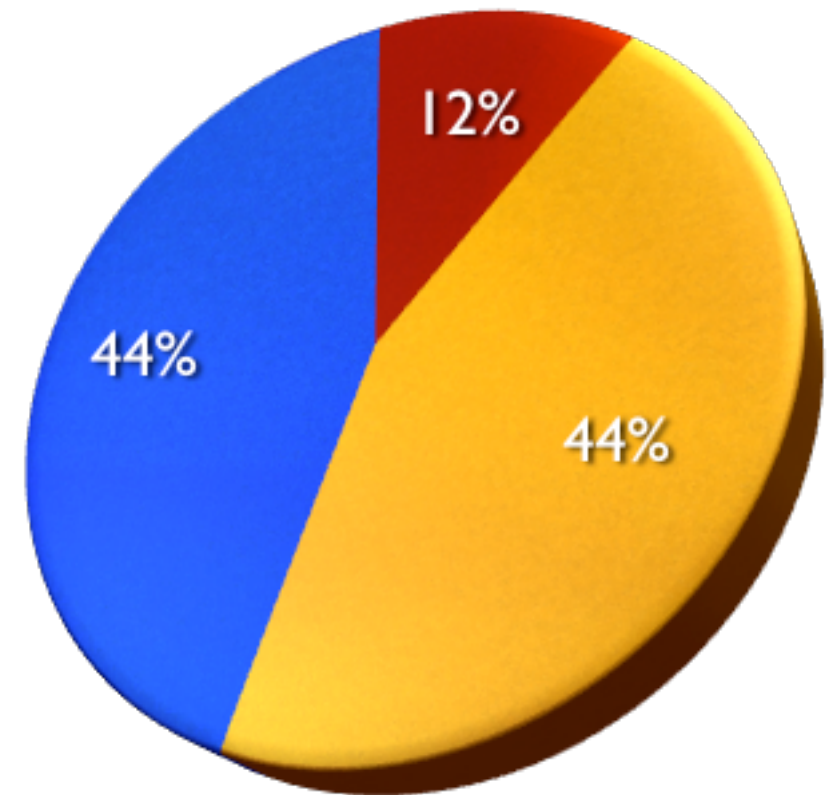
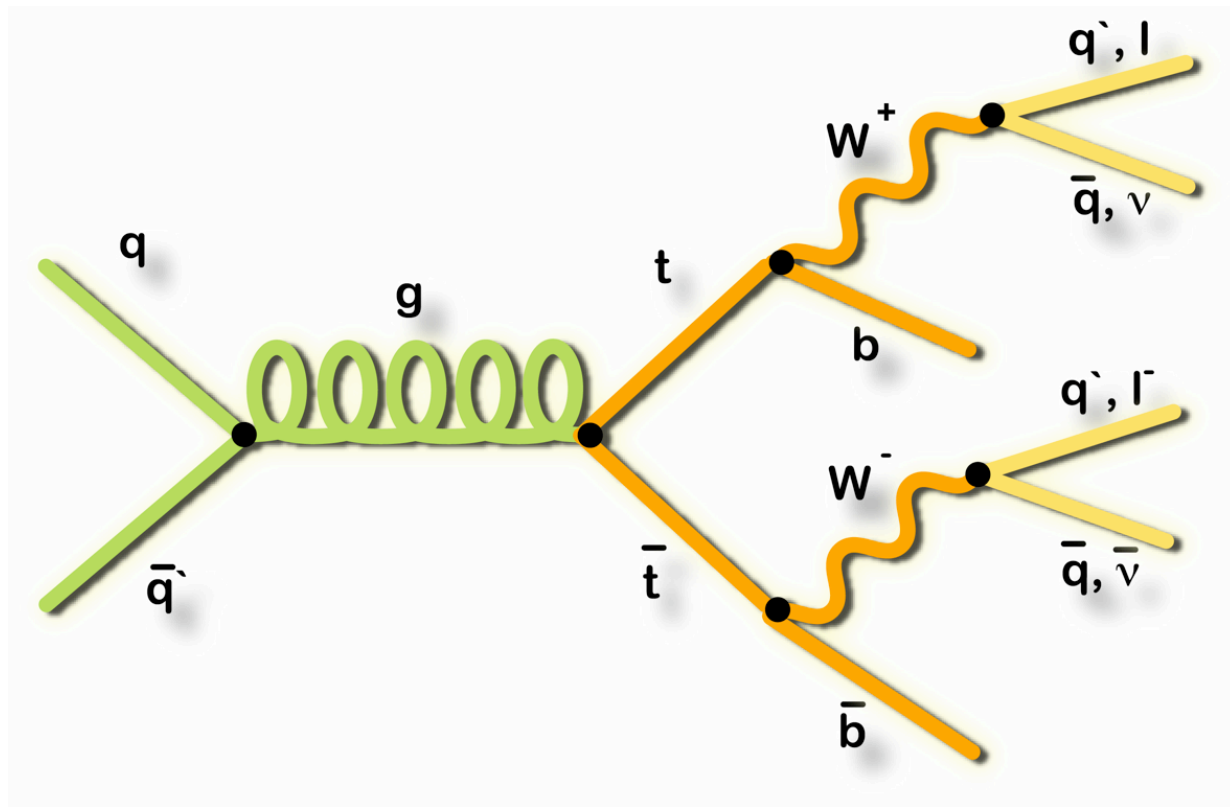
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All-Hadronic Channel



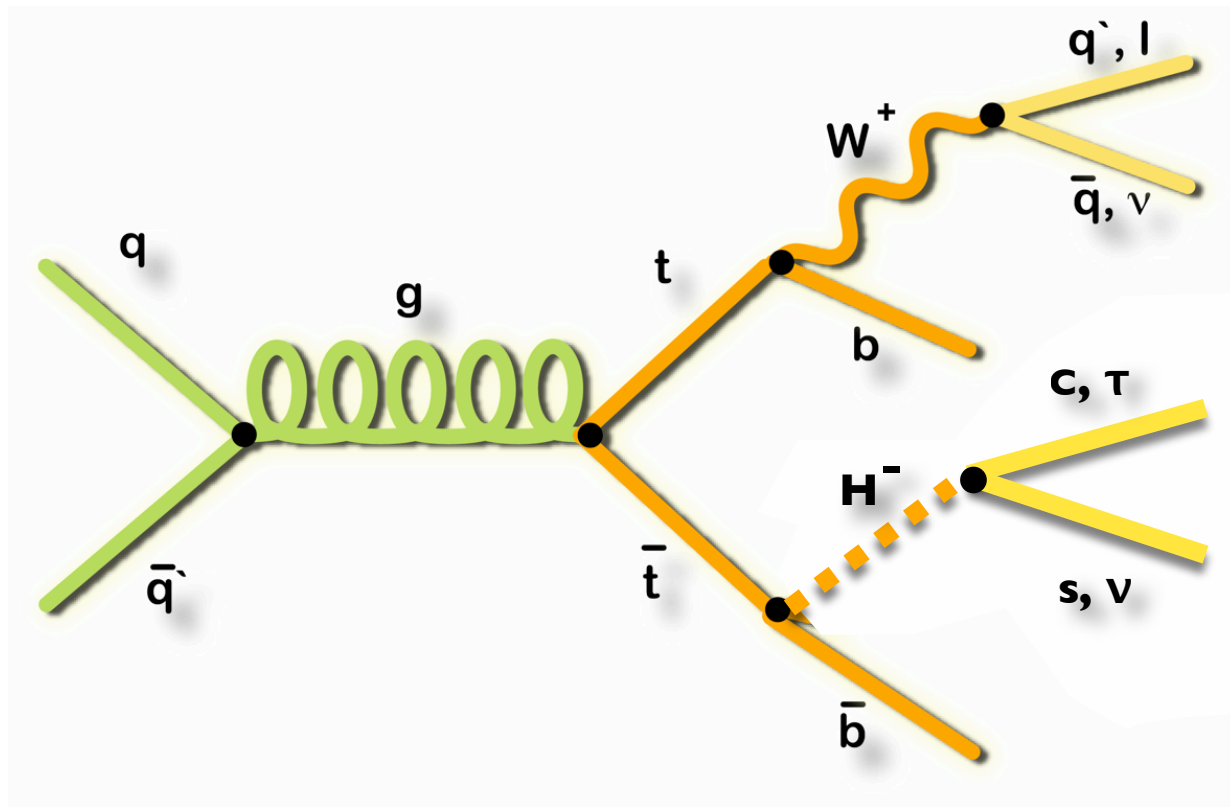
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New Physics Can Modify Decay

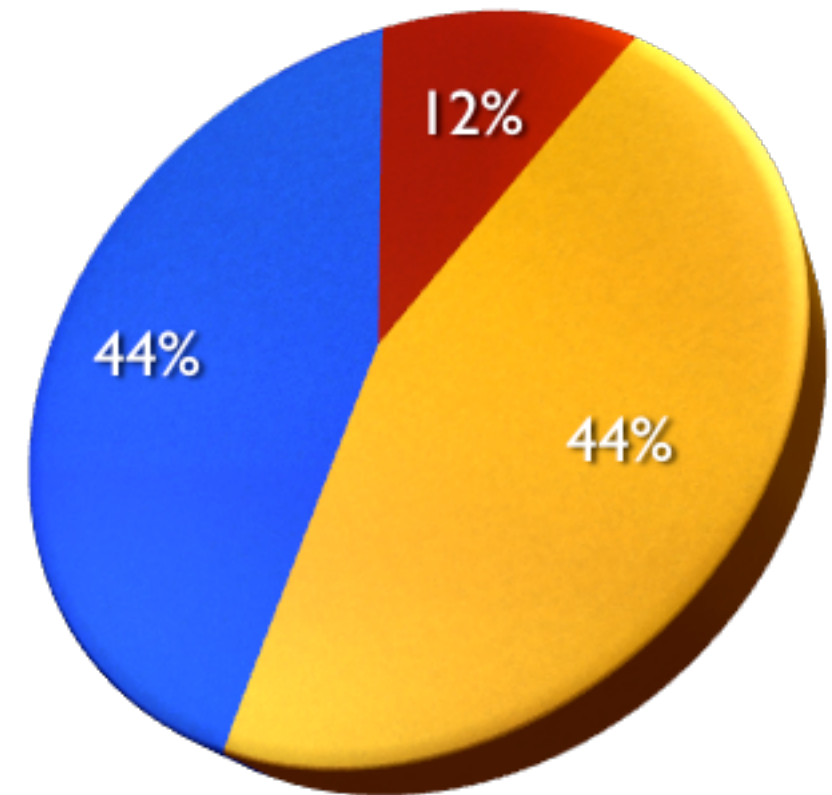


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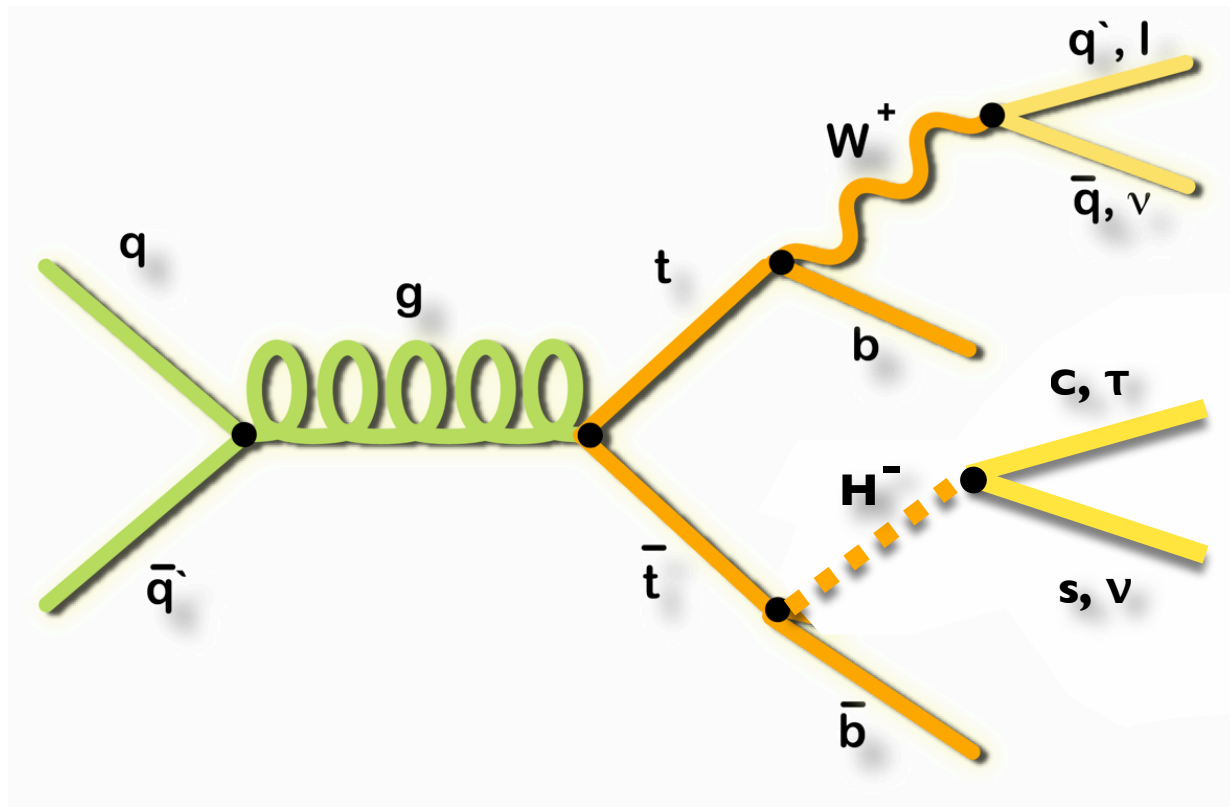


Top decaying to
charged Higgs

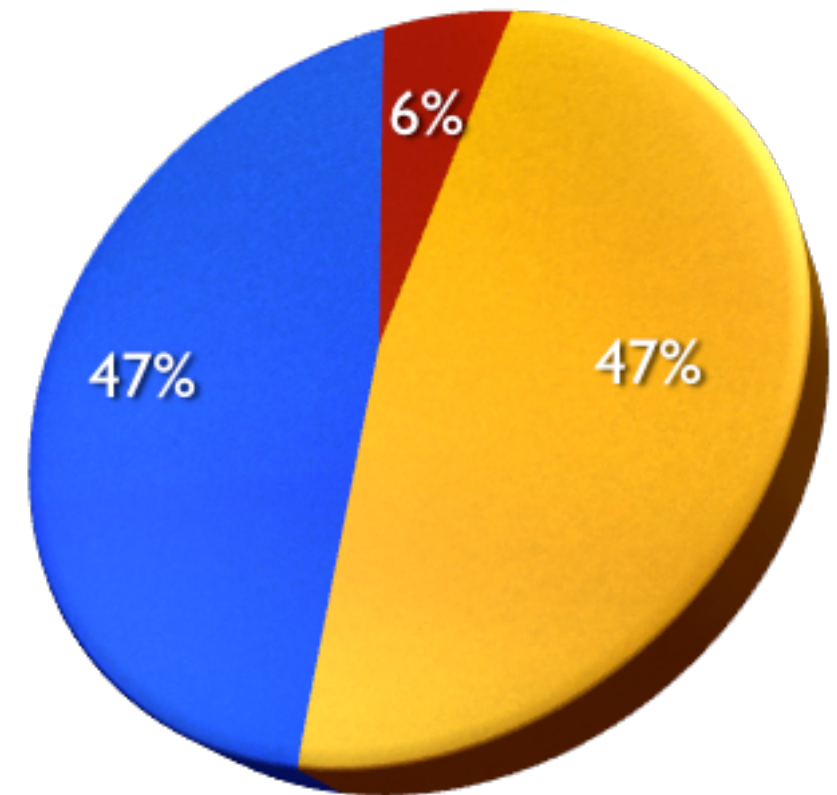


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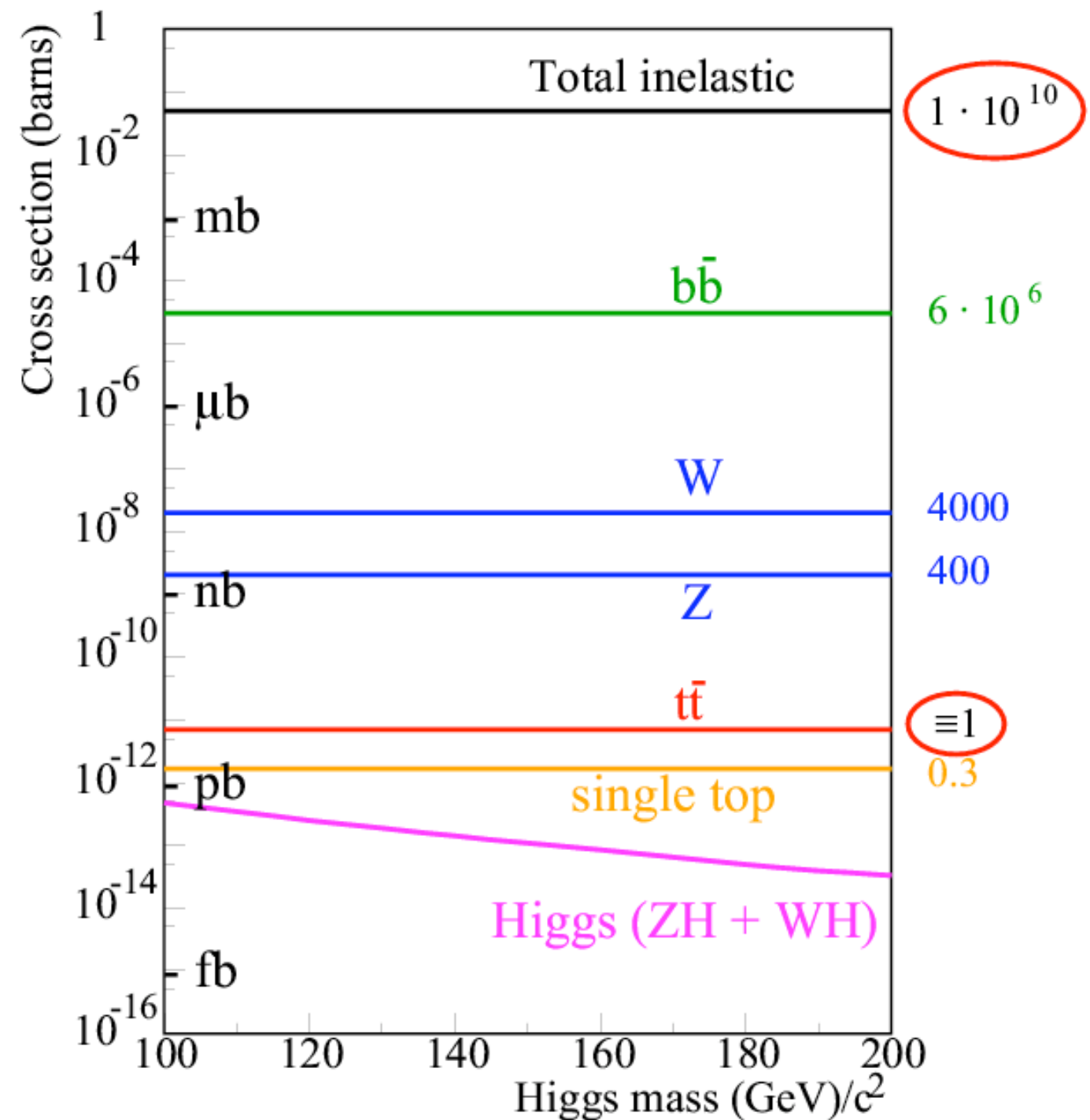


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- Lepton + Jets ($W \rightarrow l\nu$ $W \rightarrow qq$)
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Finding Top Is Difficult

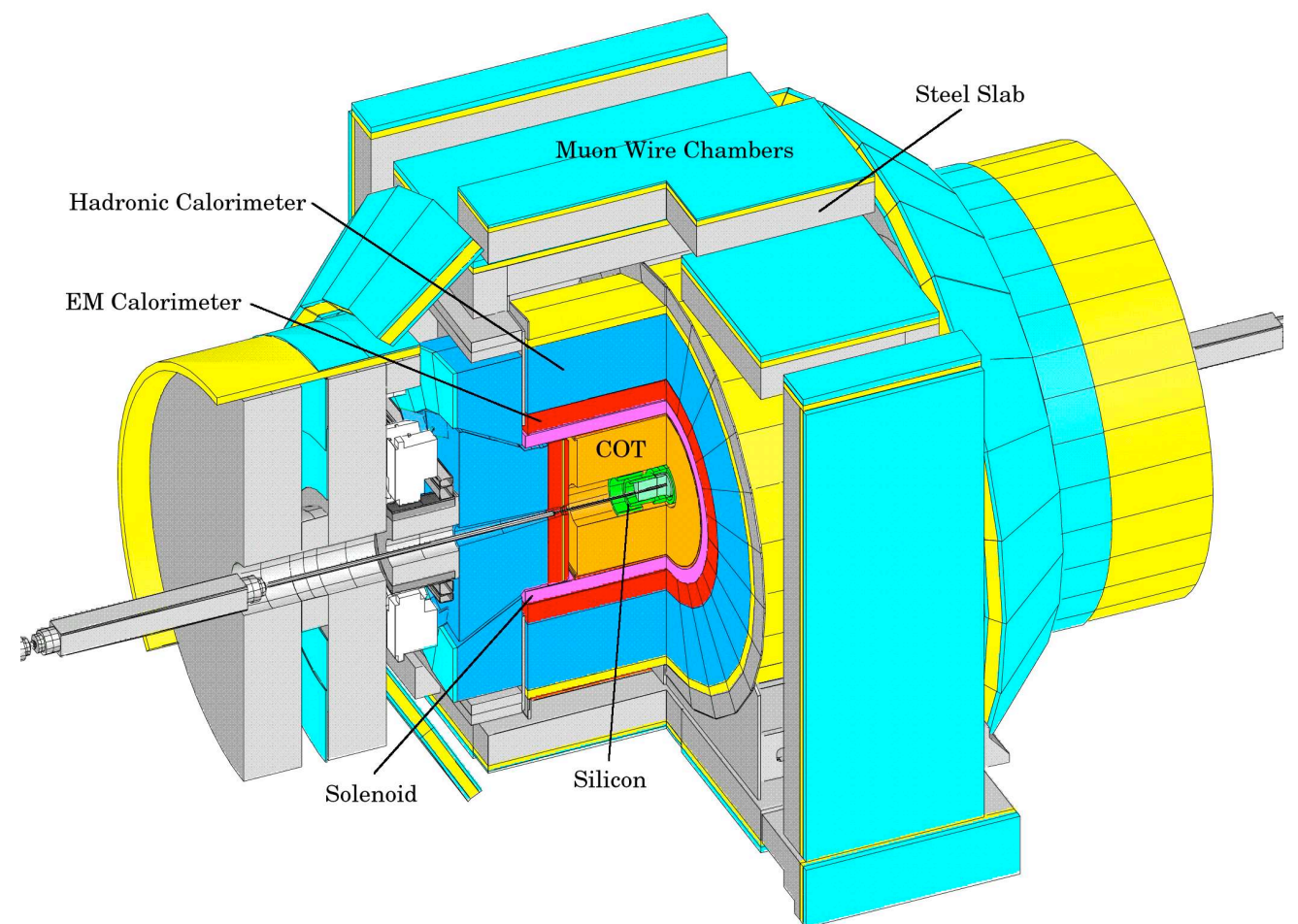
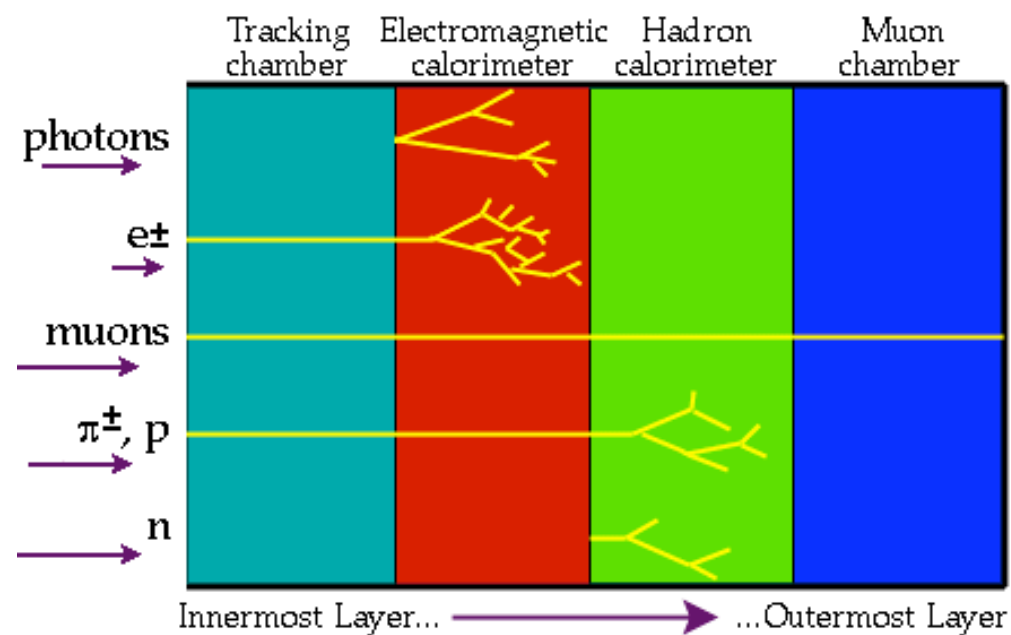
**Produce Top
~ 1 in 10 Billion
Collisions**

It's all about
understanding and
reducing backgrounds



Identifying Top Events

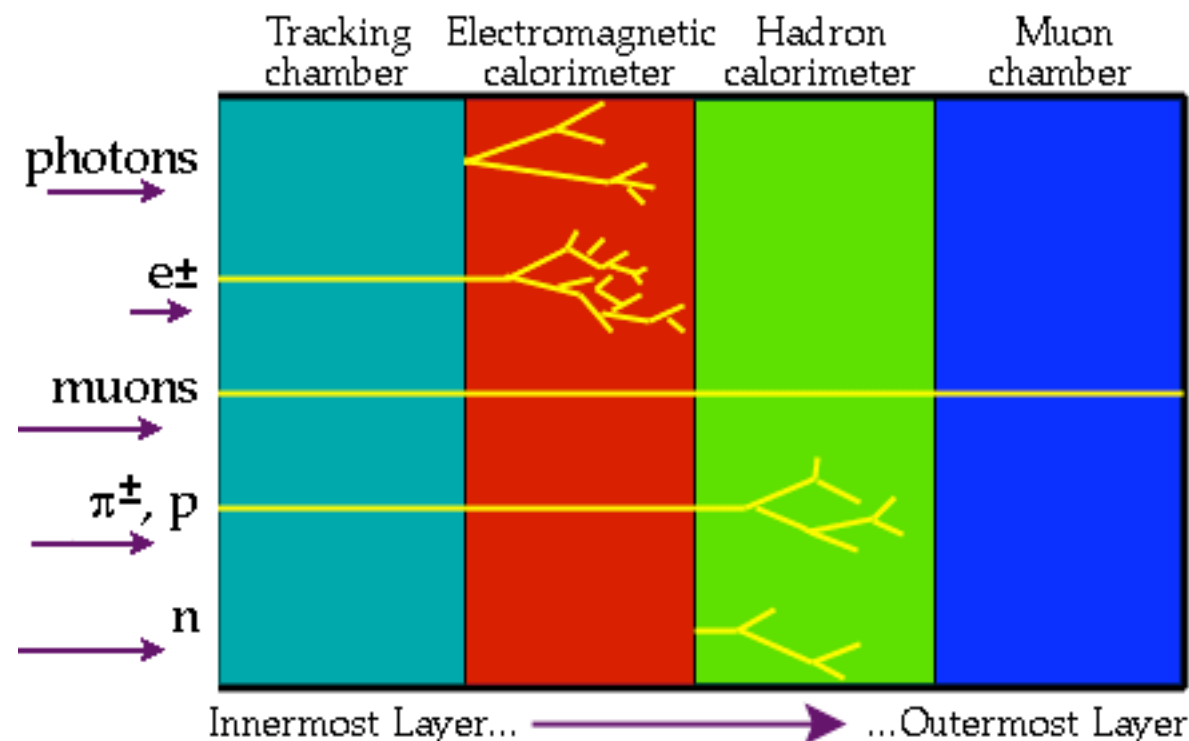
- Top events have a little bit of everything: leptons, quarks that form jets, neutrinos which leave missing transverse energy
- Each piece requires it's own unique method of identification in the detector



Lepton Identification

Electrons

- Charged track in the tracking chamber
- Deposit energy in the EM calorimeter and little in the hadronic calorimeter

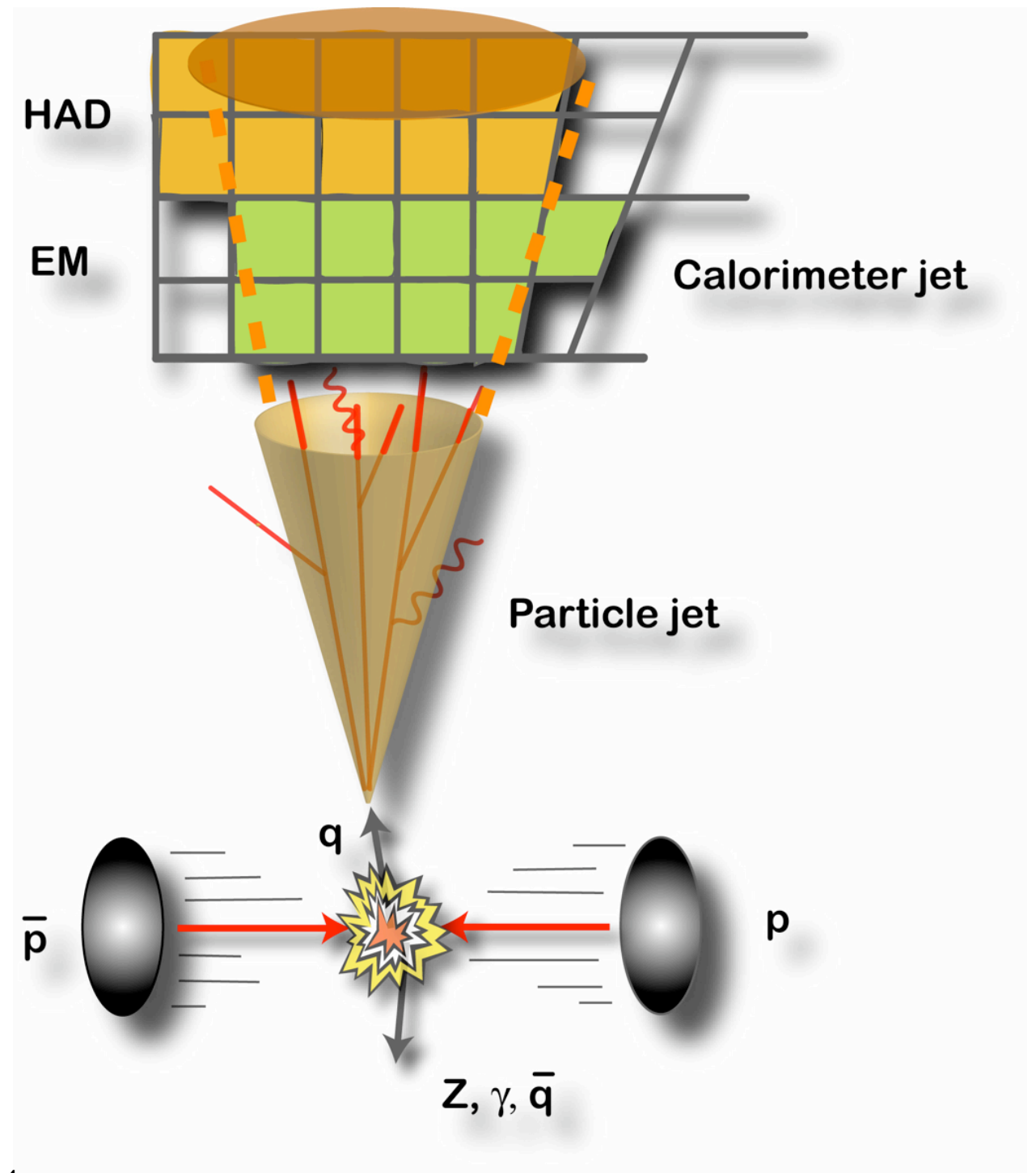


Muons

- Charged track in the tracking chamber
- Minimum amount of energy deposited in calorimeters
- Identified “stub” in muon chambers

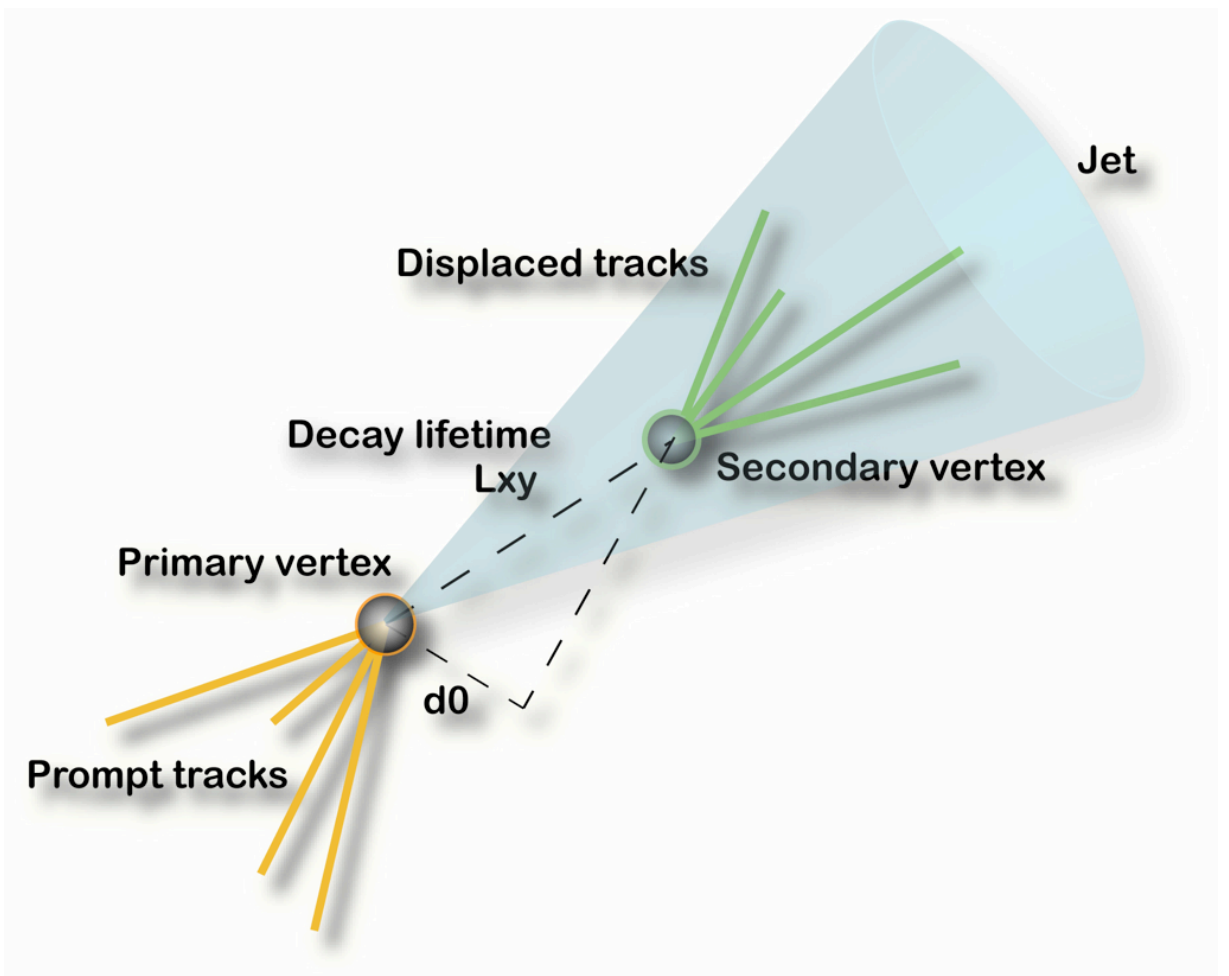
Jet Identification

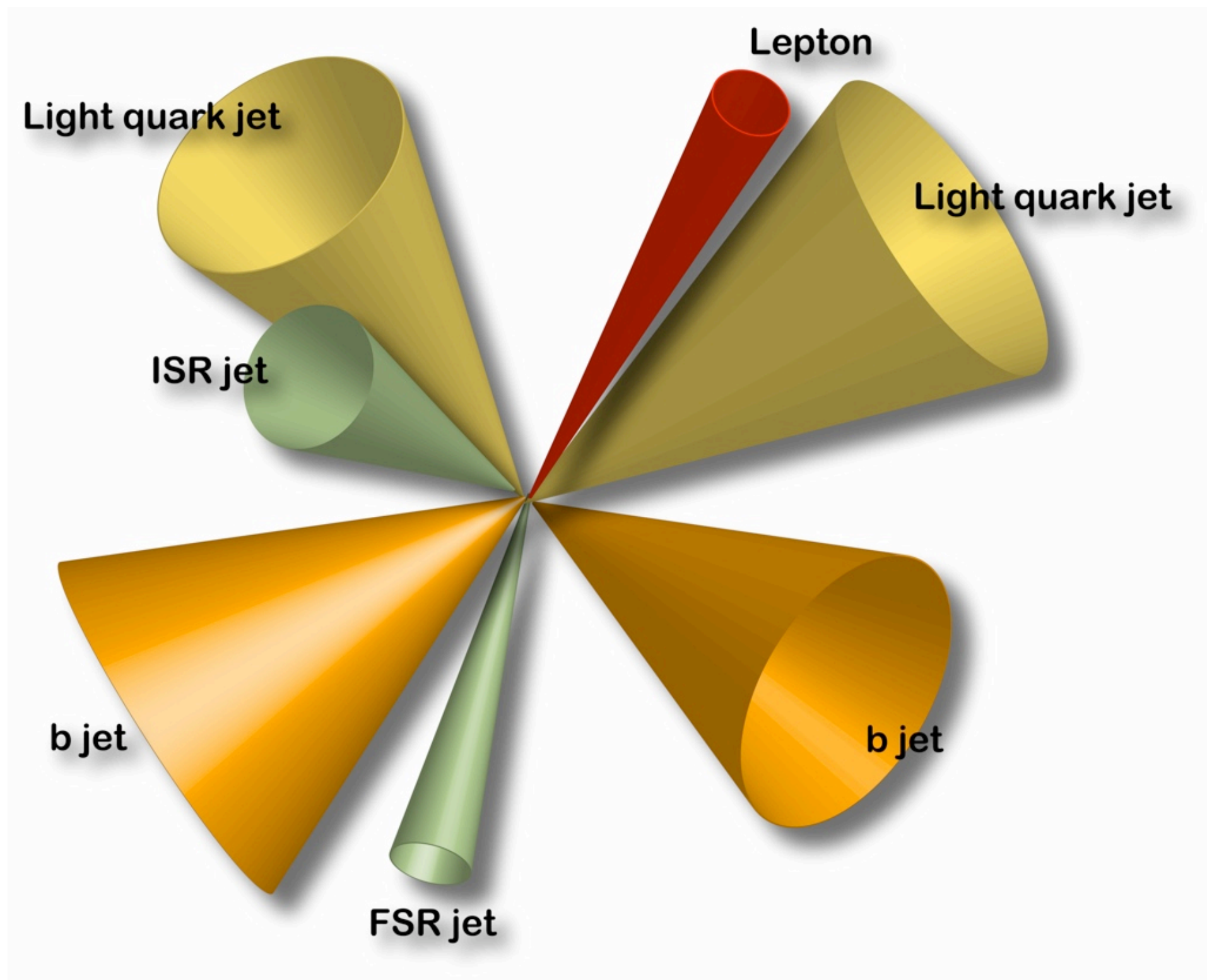
- We're looking for partons but we observe jets in the detector
- Jets are identified as cones of energy in the calorimeter towers
- Energy of jets are difficult to measure which can generally lead to large systematic uncertainties in our measurements



Bottom Quark Identification (Tagging)


- Bottom quarks generally travel a few millimeters before decay
- Look for a secondary vertex, displaced from primary, formed from two or more displaced tracks
- Suppresses background
 - QCD without bottom/charm
 - W plus light flavor jets





The Cross-Section

$$\sigma_{t\bar{t}} = \frac{N_{data} - N_{bkg}}{A \cdot \int \mathcal{L} dt}$$



Acceptance *Integrated Luminosity*

- Measuring the cross-section requires a complete understanding of the physics in our data sample
- Result feeds into all other measurements (mass, properties, searches...)

History of the Top Cross Section at CDF

Di-lepton Measurement In 1.2 fb⁻¹

$$\sigma_{t\bar{t}} = 6.2 \pm 1.1_{\text{stat}} \pm 0.7_{\text{syst}} \pm 0.4_{\text{lumi}} \text{ pb}$$

Lepton + Jets Pretag Measurement In 1.1 fb⁻¹

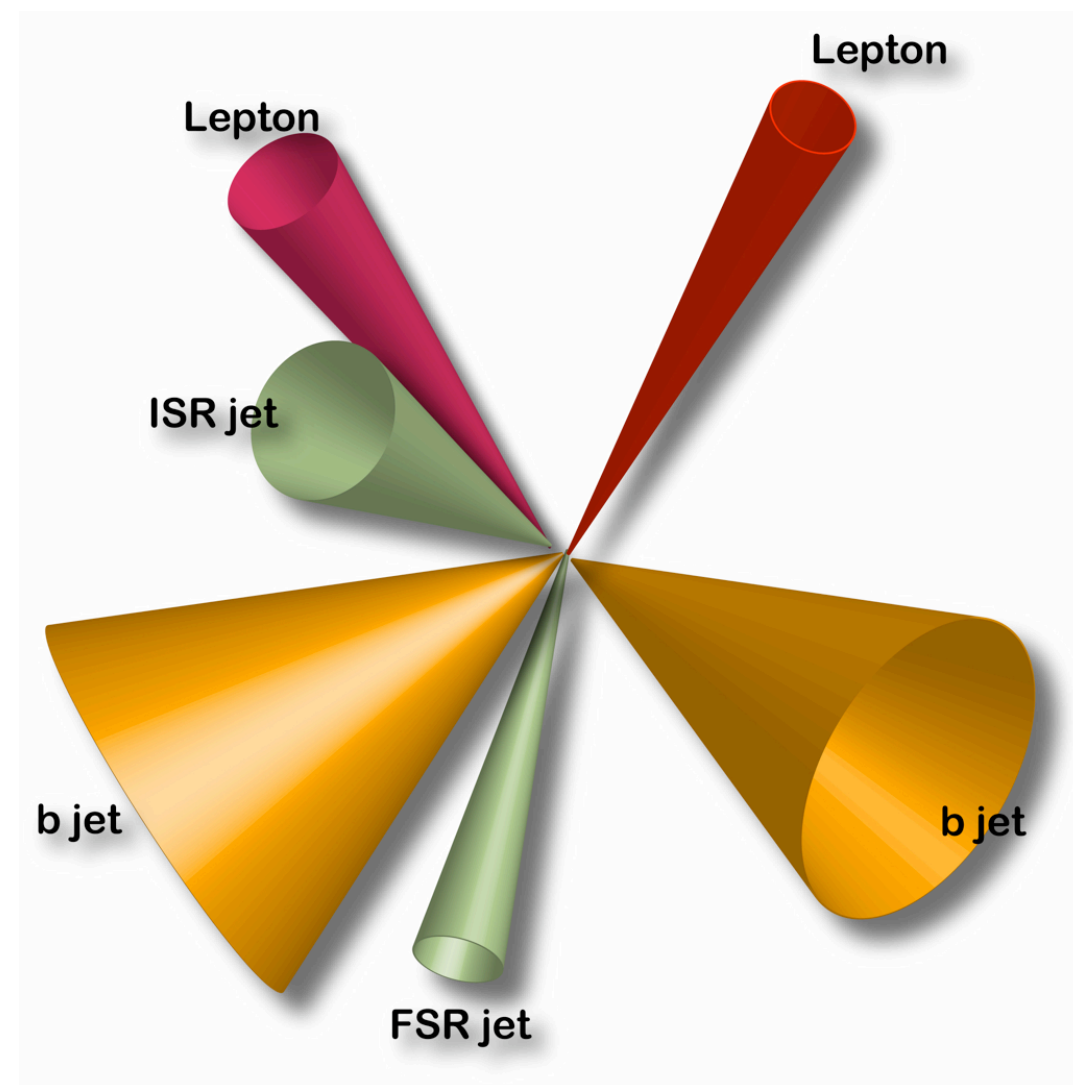
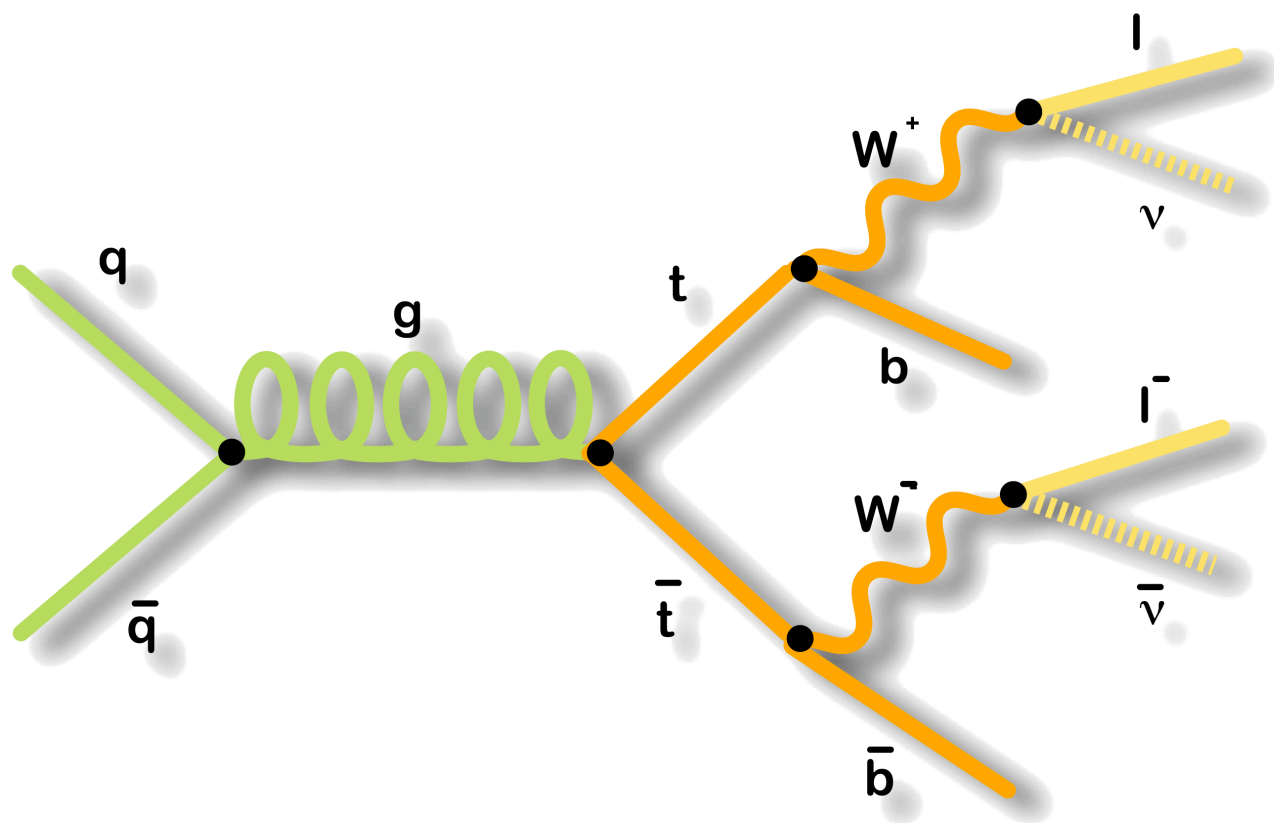
$$\sigma_{t\bar{t}} = 6.0 \pm 0.6_{\text{stat}} \pm 0.9_{\text{syst}} \text{ pb}$$

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$$\sigma_{t\bar{t}} = 8.2 \pm 0.5_{\text{stat}} \pm 0.8_{\text{syst}} \pm 0.5_{\text{lumi}} \text{ pb}$$

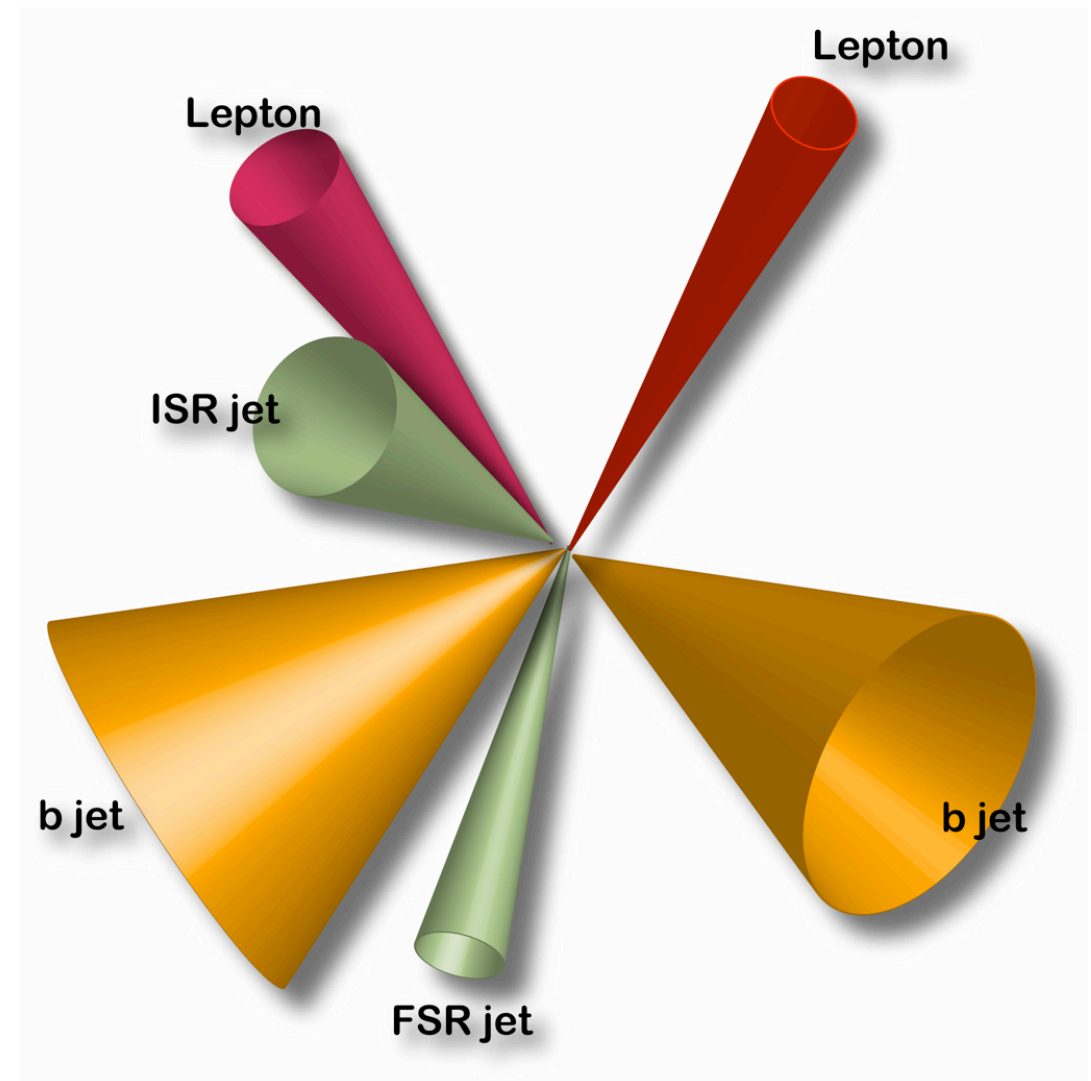
B-Tag Measurement Has Historically Been High...

Di-lepton Channel



Di-lepton Channel

- ≥ 2 Jets ($E_t \geq 15$ GeV and $\eta < 2.4$)
- 2 Electrons or Muons ($P_t \geq 20$ GeV) of opposite sign
- ≥ 25 GeV Missing Transverse Energy
- $|\Delta\Phi| > 30^\circ$ between MET and Leading Jet



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$t\bar{t}$
 Z/γ^*
 WW
 WZ
 ZZ
Fakes

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$t\bar{t}$
 Z/γ^*
 WW
 WZ
 ZZ
Fakes

S:B ~ 3:1

Monte Carlo Based Estimates

$$N = \sigma \cdot \int \mathcal{L} dt \cdot A$$

Z/γ^*
 WW
 WZ
 ZZ

Monte Carlo Based Estimates

$$N = \sigma \cdot \int \mathcal{L} dt \cdot A$$

experiment or theory
 ↓
Measured ↗ ↖ *From Monte Carlo*

*Z/γ**
WW
WZ
ZZ

Backgrounds

Process	Events
$t\bar{t}$ (6.7 pb) Z/γ^* WW WZ ZZ	
Fakes	
Sum Data	

Backgrounds

Process	Events
$t\bar{t}$ (6.7 pb)	110.6
Z/γ^*	26.6
WW	10.2
WZ	2.9
ZZ	1.5
Fakes	
Sum Data	

Fakes

- Anything that can mimick one of the leptons
- Mostly QCD which cannot be estimated by a Monte Carlo approach
- Fakes dominate same-sign dileptons events
- If we assume the fake-rate is independent of charge, we can use the same sign rate to predict fakes in our signal region

Backgrounds

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Backgrounds

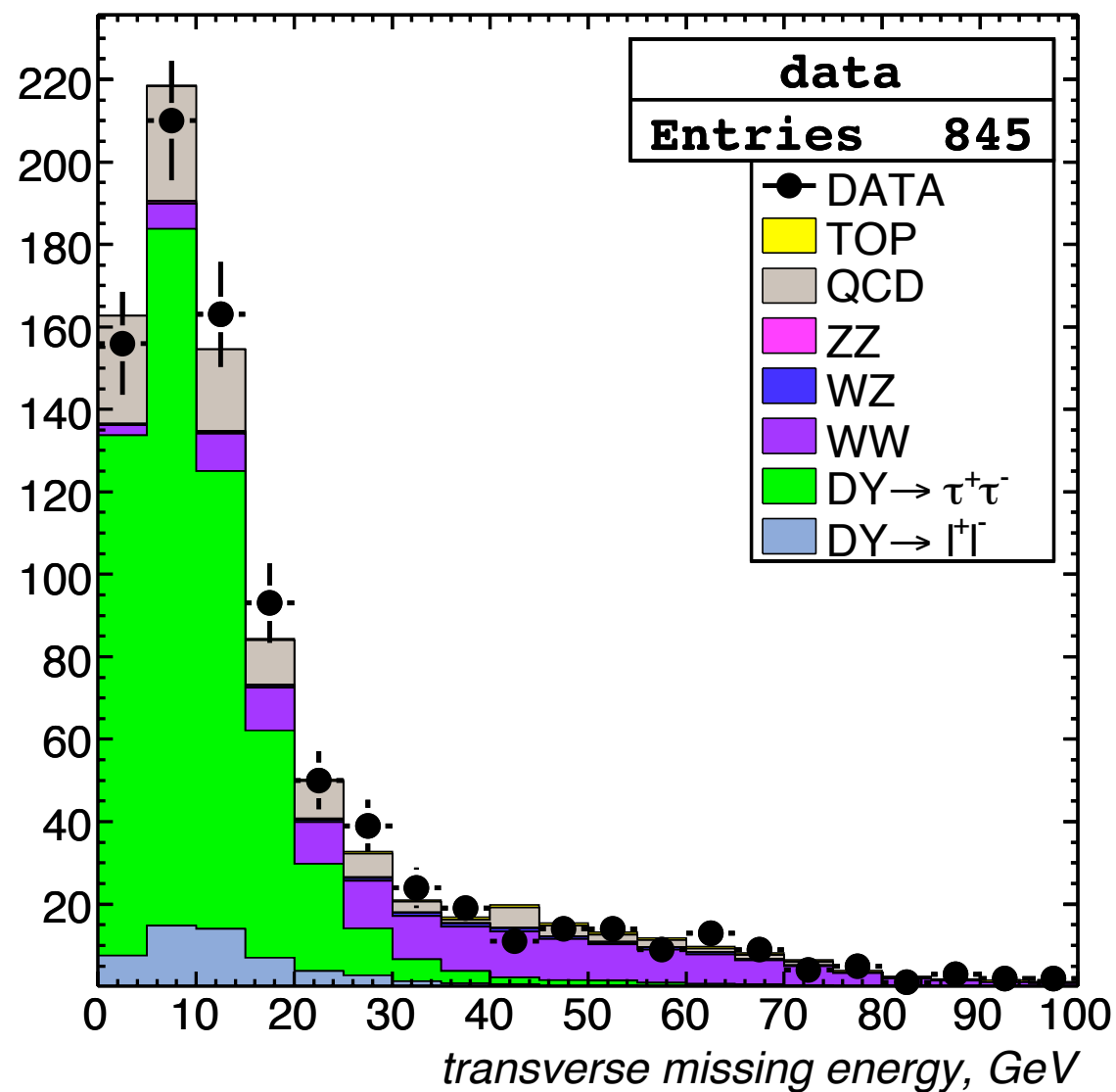
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ZZ	1.5
Fakes	10.8
Sum Data	162.5 ± 4.5

Do we believe it?

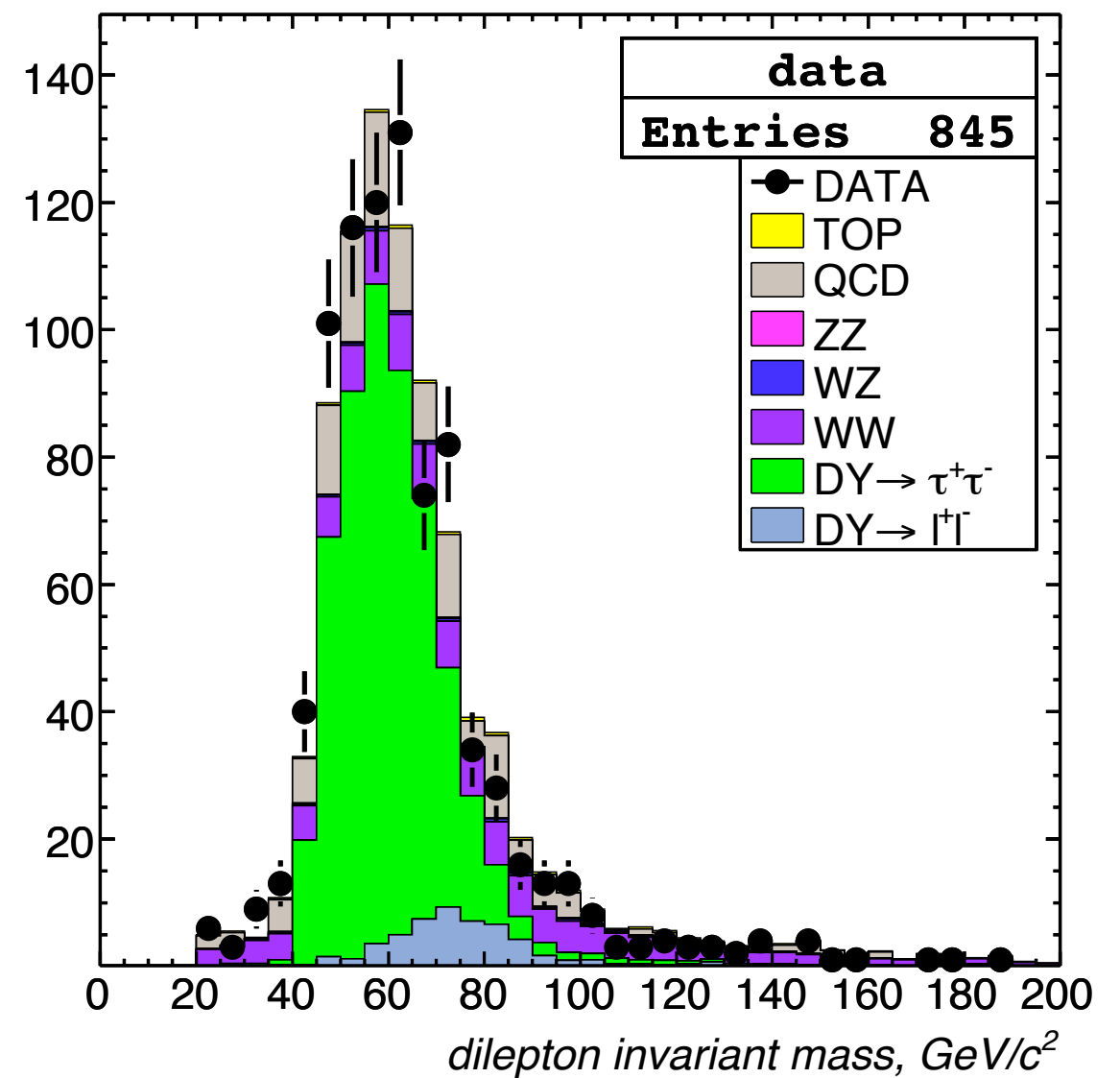
- Use a side-band region, dominated by backgrounds, to test method
- Di-lepton events with ≤ 1 Jets
 - e^-e^+ and $\mu^-\mu^+$ dominated entirely by Drell-Yan
 - More interesting are $e\mu$ events which have a more diverse process content

Control Region

Electron Muon Dileptons With $N_{jet} \leq 1$



Electron Muon Dileptons With $N_{jet} \leq 1$



Backgrounds

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Measurement in 2.8 fb⁻¹

$$\sigma_{t\bar{t}} = \frac{N_{data} - N_{bkg}}{A \cdot \int \mathcal{L} dt}$$

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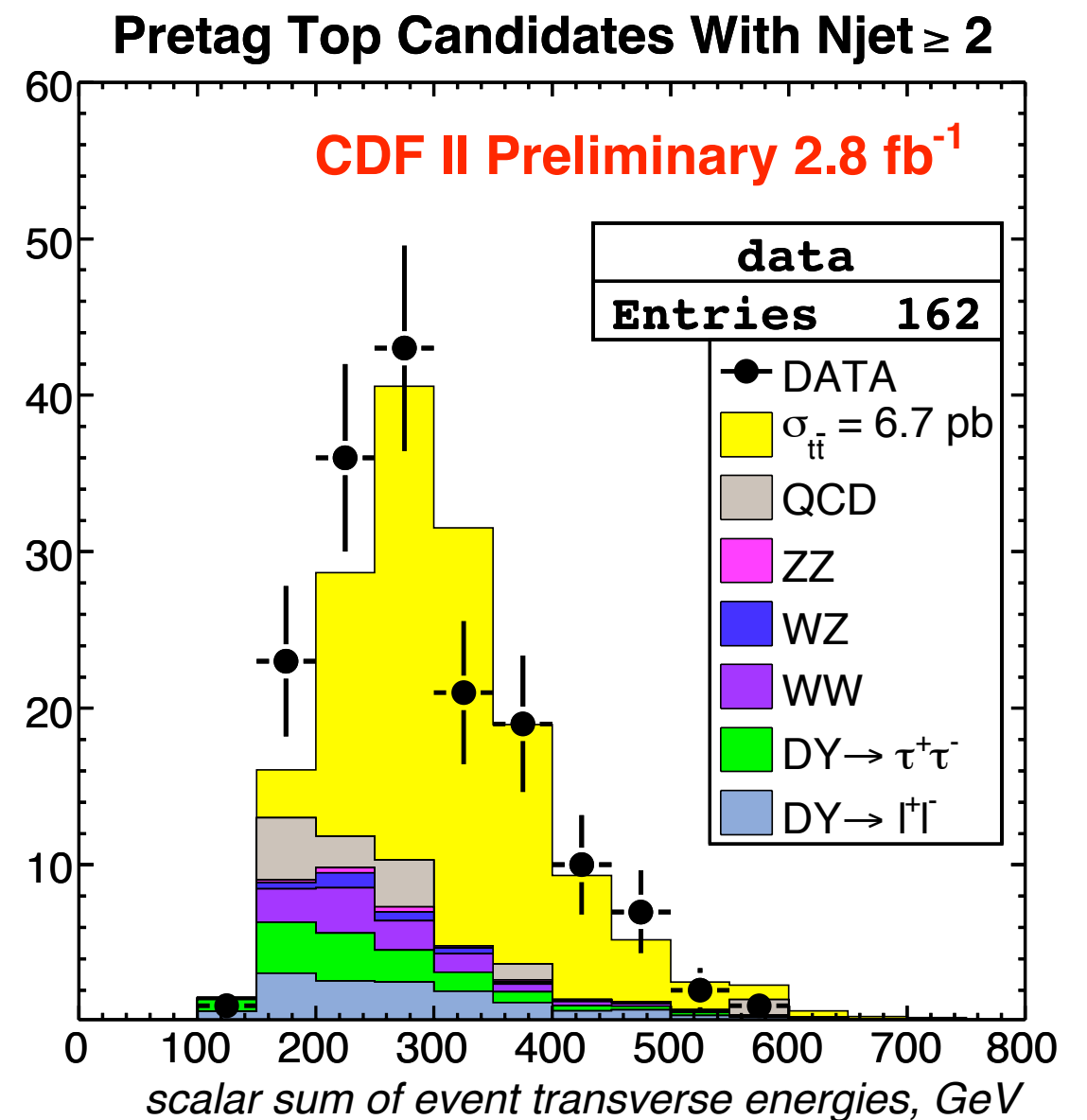
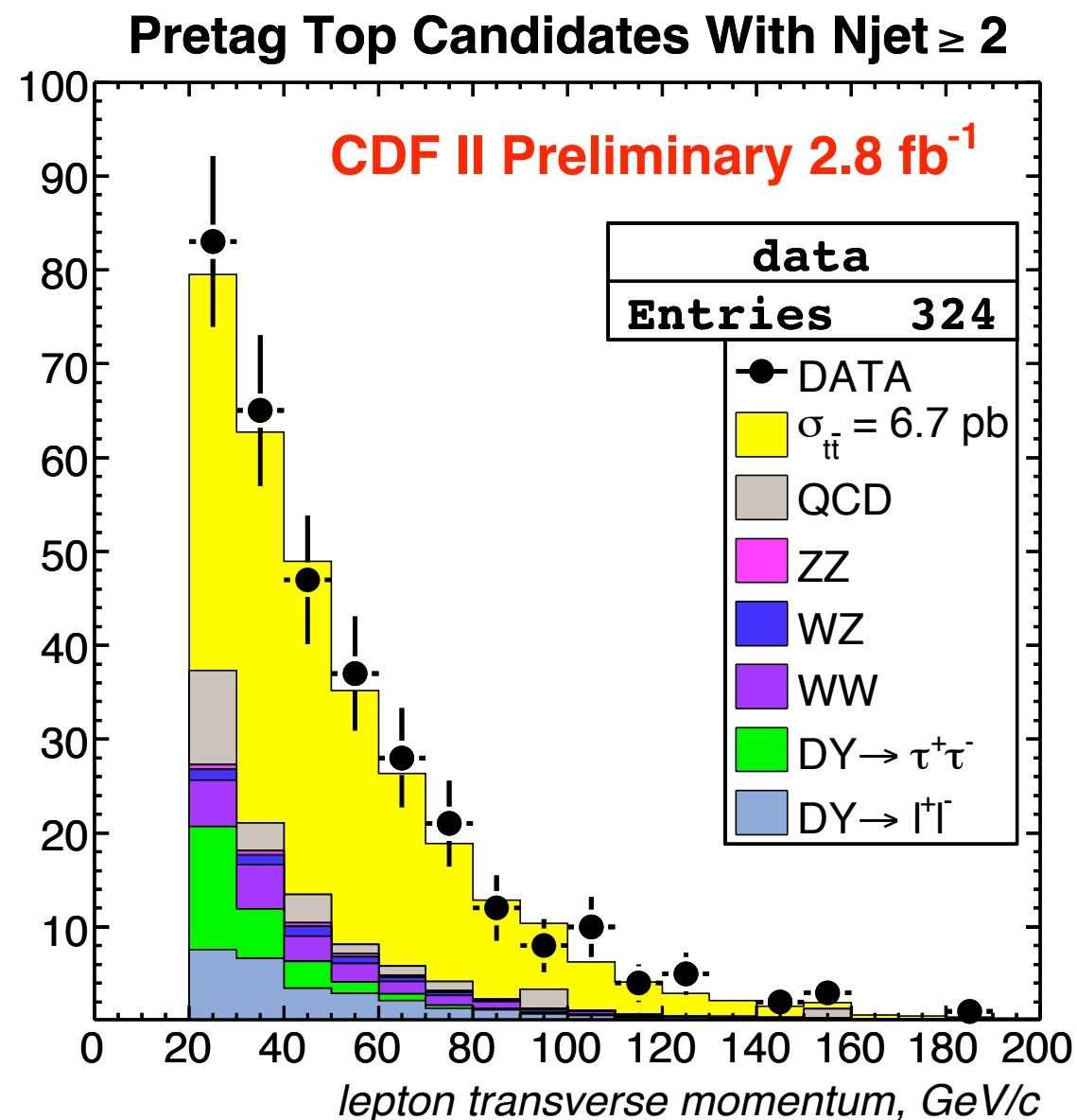
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$$\sigma_{t\bar{t}} = 6.7 \pm 0.8_{\text{stat}} \pm 0.4_{\text{sys}} \pm 0.4_{\text{lum}} \text{ pb}$$

$$@ M_t = 175 \text{ GeV}/c^2$$

How do the Kinematics Look?



History of the Top Cross Section at CDF

Di-lepton Measurement In 1.2 fb^{-1}

$$\sigma_{t\bar{t}} = 6.2 \pm 1.1_{\text{stat}} \pm 0.7_{\text{syst}} \pm 0.4_{\text{lumi}} \text{ pb}$$

Lepton + Jets Pretag Measurement In 1.1 fb^{-1}

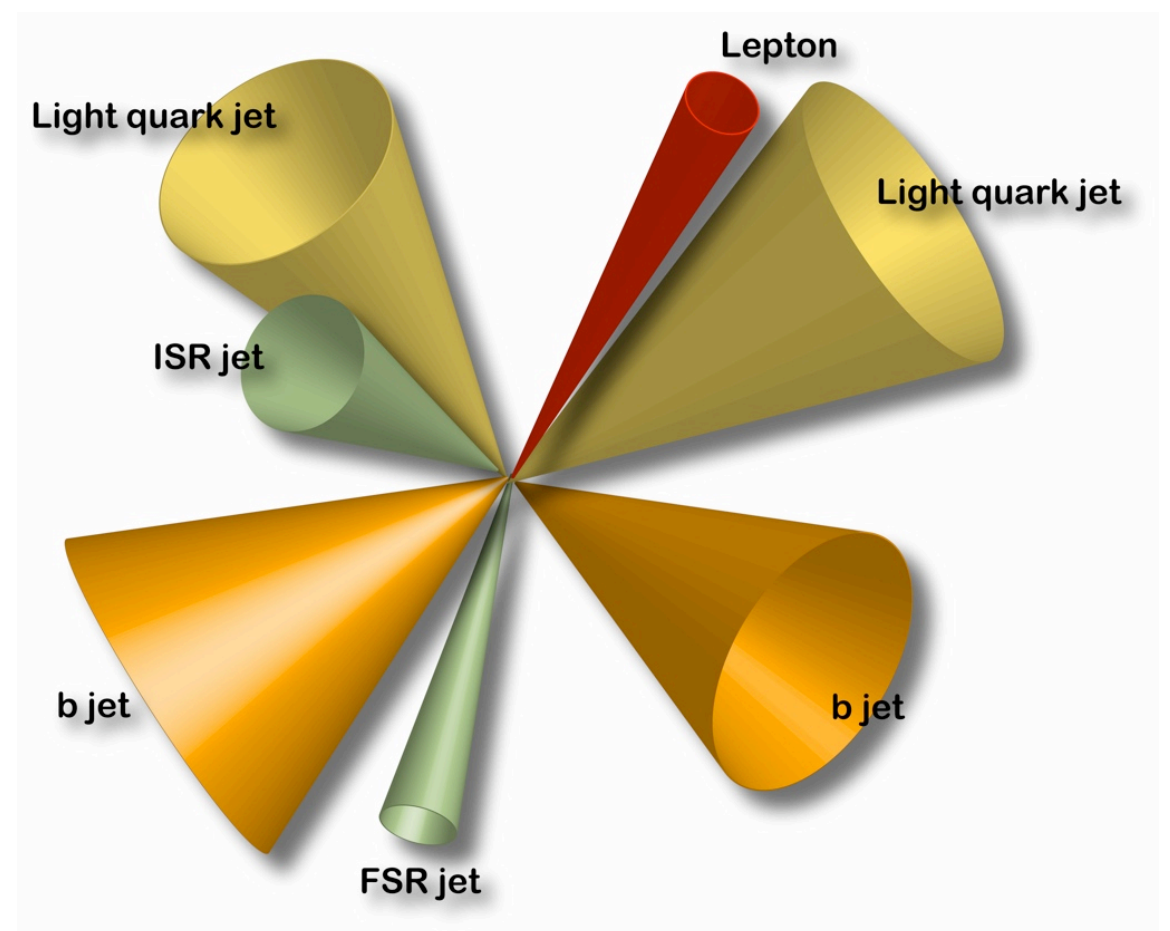
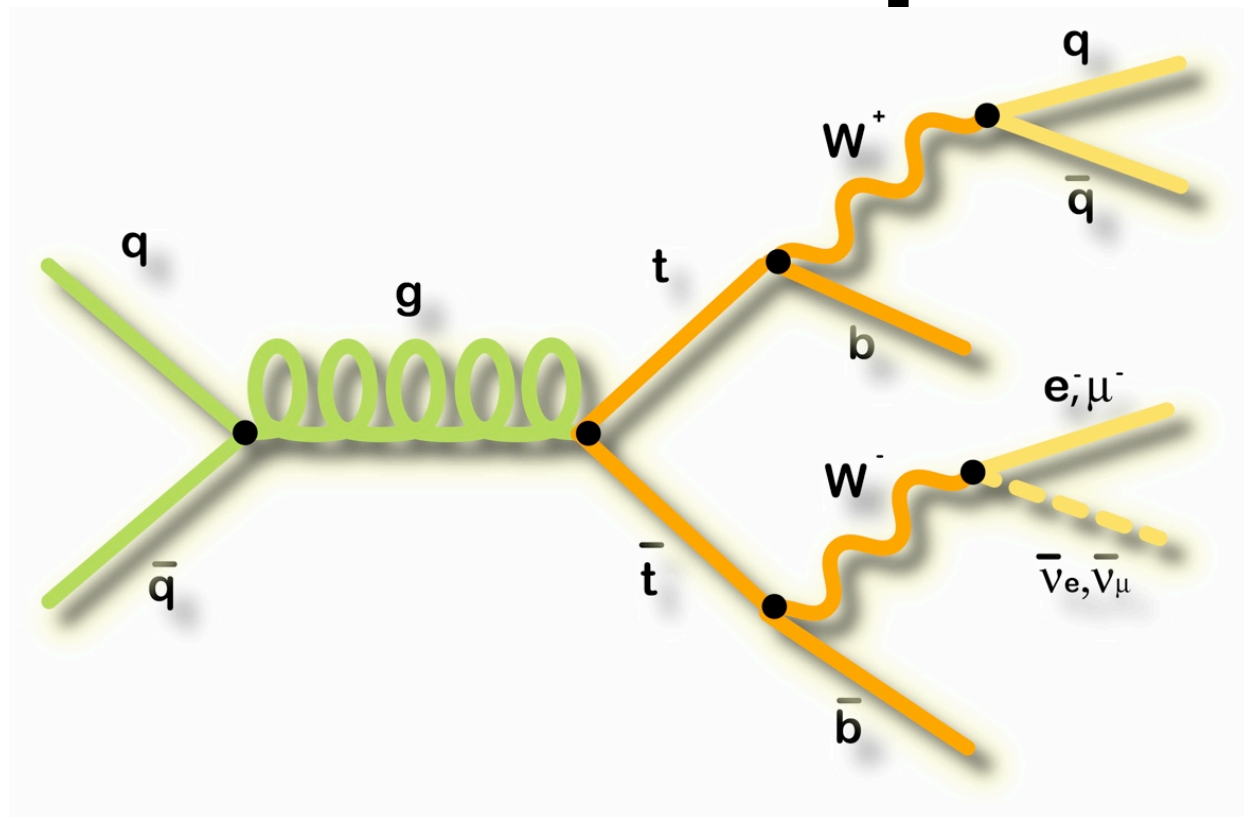
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Lepton + Jets B-Tag Measurement In 1.1 fb^{-1}

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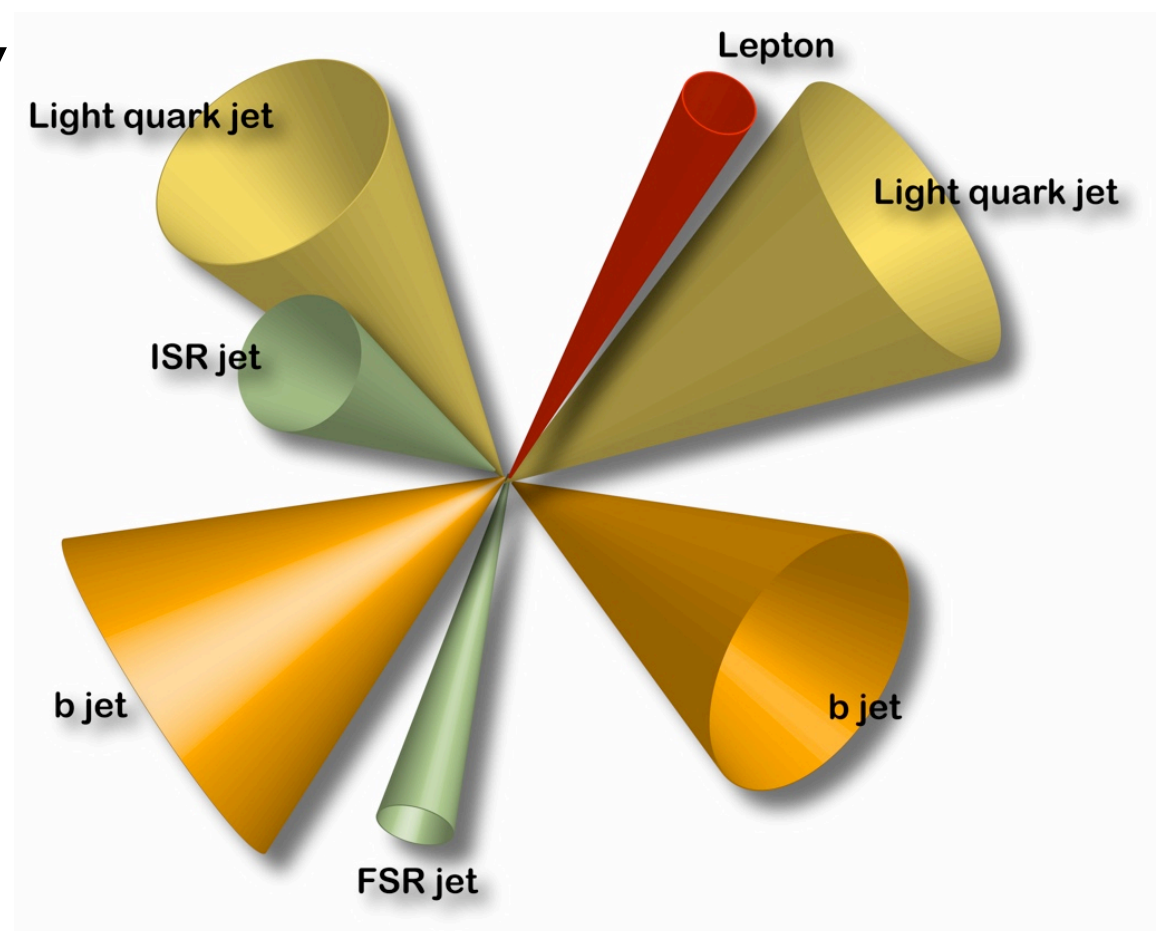
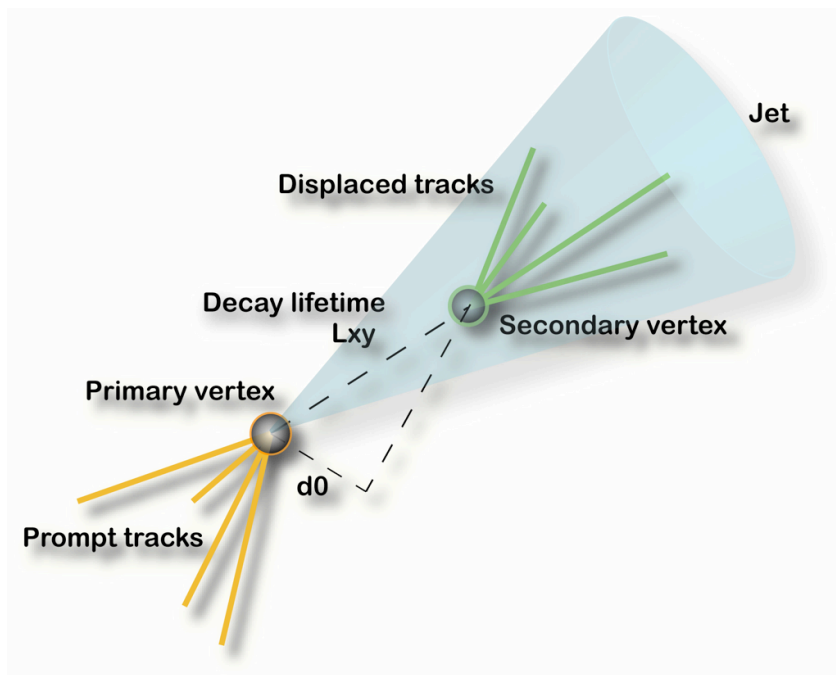
B-Tag Measurement Has Historically Been High...

Bottom Tagging in Lepton + Jets



Bottom Tagging in Lepton + Jets

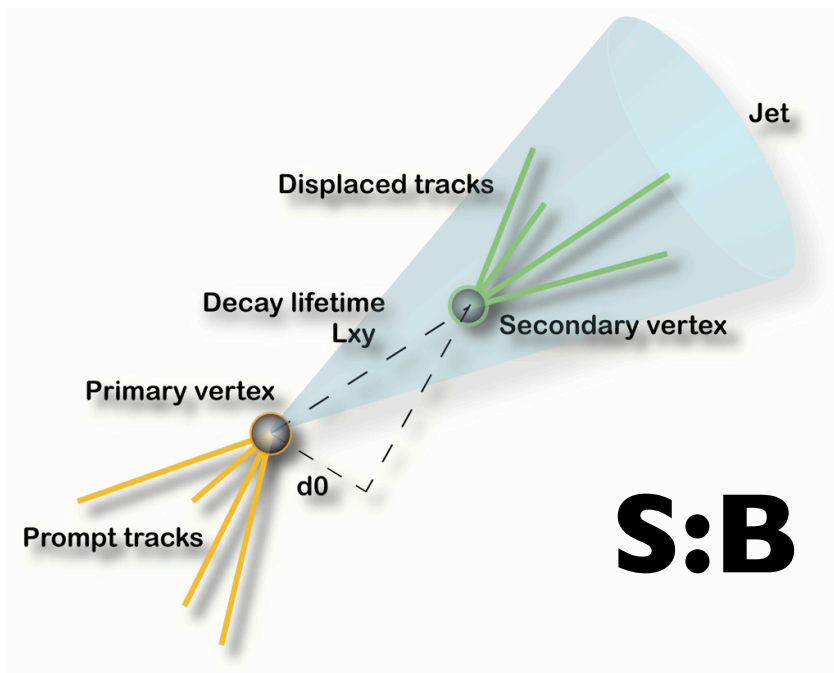
- ≥ 3 Jets ($E_t \geq 20$ GeV and $\eta < 2.0$)
- 1 Electron or Muon ($P_t \geq 20$ GeV)
- ≥ 25 GeV Missing Transverse Energy
- ≥ 1 Bottom Tagged Jet



Physics Processes

- ≥ 3 Jets ($E_t \geq 20$ GeV and $\eta < 2.0$)
- 1 Electron or Muon ($P_t \geq 20$ GeV)
- ≥ 25 GeV Missing Transverse Energy
- ≥ 1 Bottom Tagged Jet

$t\bar{t}$
 $W + Jets$
 QCD
 $Electroweak$



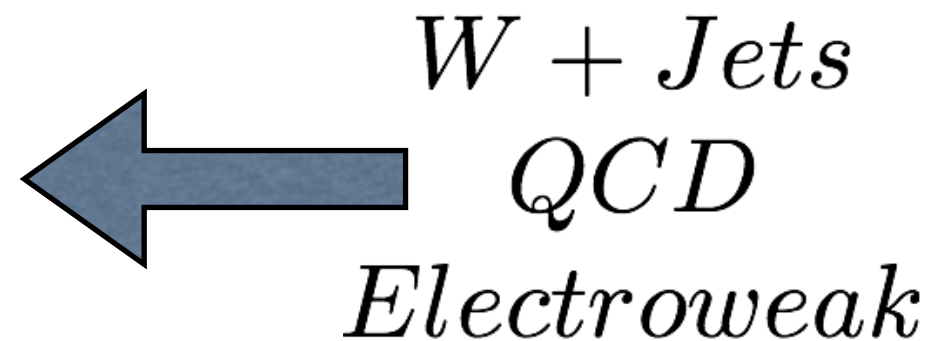
$$\mathbf{S:B} \sim \mathbf{1:3} \xrightarrow{\text{tagging}} \mathbf{1:1}$$

Monte Carlo Based

$$N = \sigma \cdot \int \mathcal{L} dt \cdot A \quad \leftarrow \begin{array}{l} W + Jets \\ QCD \\ Electroweak \end{array}$$

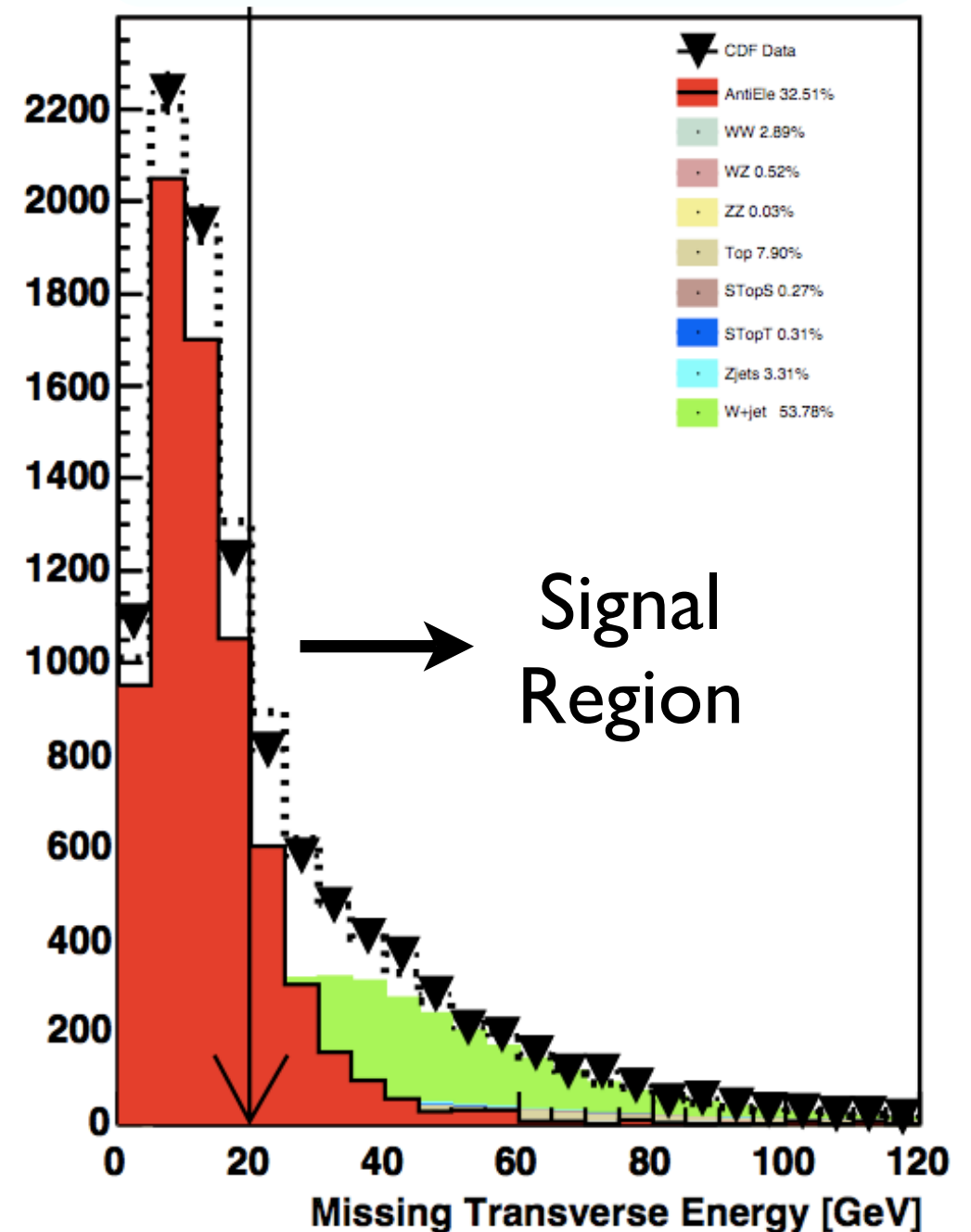
QCD

- QCD is very difficult to model with Monte Carlo
- Use data-driven approach - model QCD by all-jets sample or sample of leptons which failed ID cuts



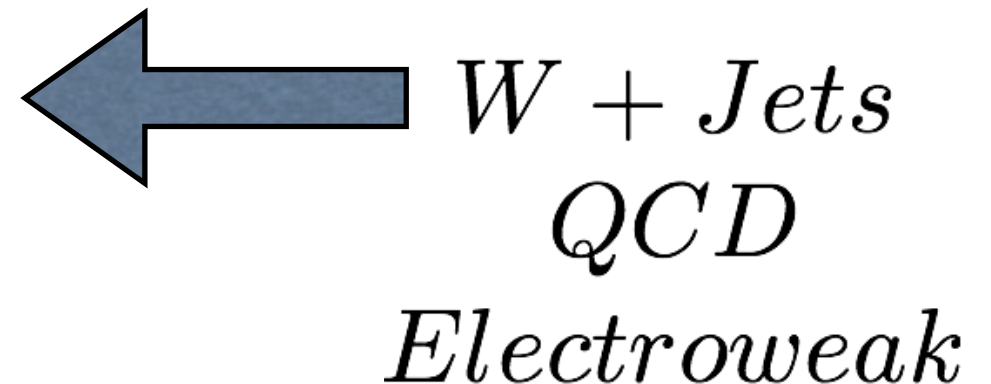
QCD

- QCD is very difficult to model with Monte Carlo
- Use data-driven approach - model QCD by all-jets sample or sample of leptons which failed ID cuts
- Fit QCD and W+jets in low MET region - dominated by QCD
- Extract predicted fraction of events from QCD in signal region



W + Jets

- W + Jets can be modeled by Monte Carlo but there are two difficulties that arise when we require a bottom tag

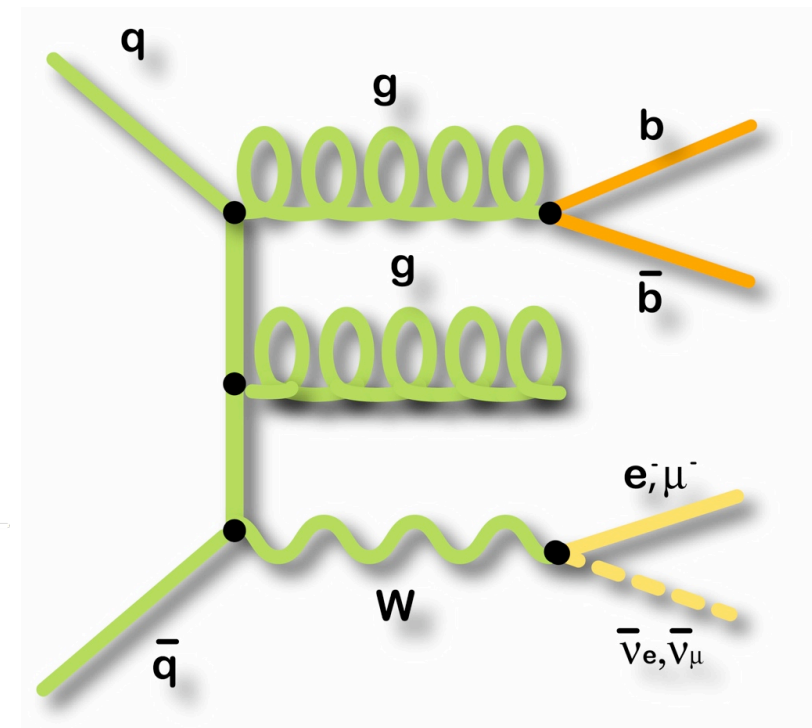


- First, the rate of tagging bottom & charm is over-estimated and the rate of mis-identifying them is underestimated
- Second, the cross-section for W associated with jets from bottom & charm is not well understood

W + bottom/charm

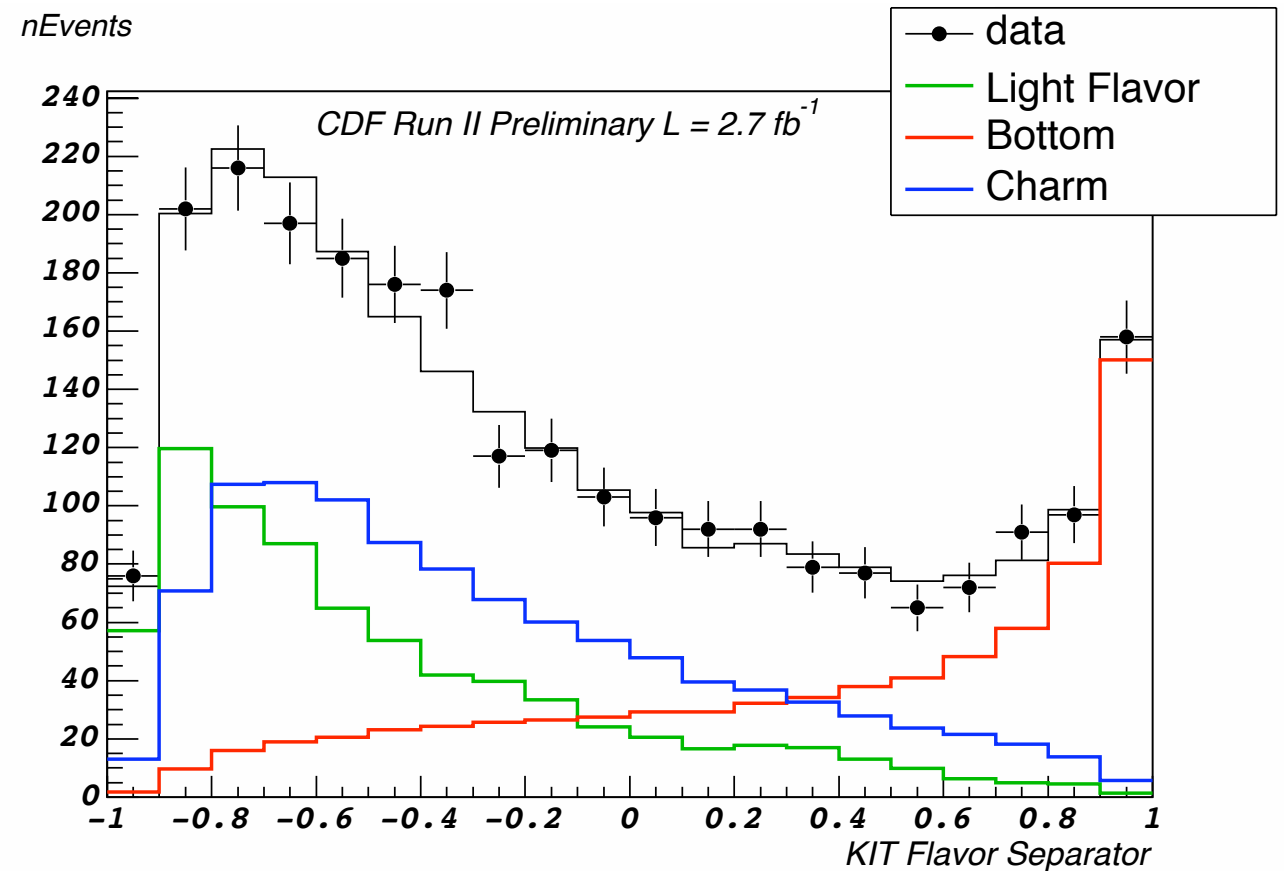
- Because we're tagging bottom quarks, the relative amount of W + heavy flavor events vs W + light flavor becomes important
- This is not well understood theoretically and difficult to model in Monte Carlo
- A data-driven approach is used to correct the fraction of the W+jets sample associated with heavy flavor

$$N_{W+Jets} = (N_{pretag} - N_{mc\ based} -$$



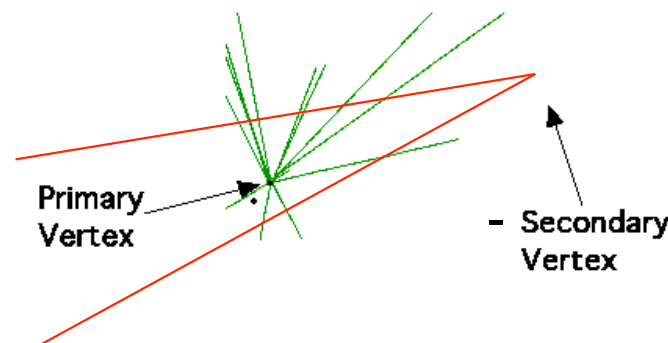
W + bottom/charm

- Effectively, we measure the fraction of W + bottom/charm in W + jets events in a non-signal region (W + 1 jet)
- Neural network used to identify bottom/charm/light flavor events
- Simultaneously fit for bottom, charm, and light flavor fractions
- Compare to Monte Carlo to derive a correction factor and apply this to the W + jets prediction in the signal region



W + light flavor (mistags)

- W + light flavor jets sneak in by a mis-identified bottom/charm jet (call these mistags)
- Unfortunately, monte carlo is not tuned to handle this effect
- Instead, a data-driven parameterization is used to estimate the probability that a given jet will be mis-tagged

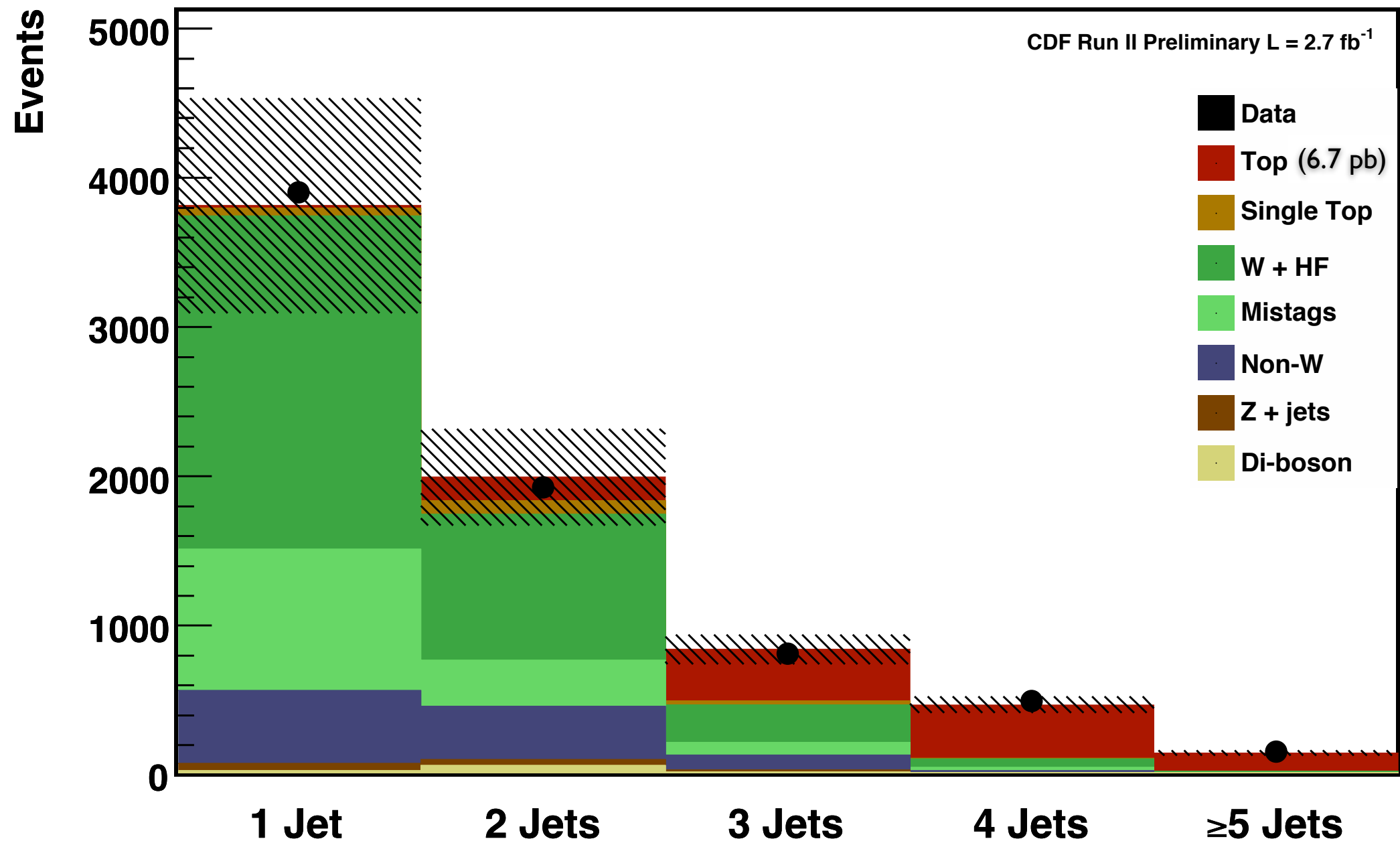


- This is applied to our pre-tag data sample to produce a prediction of the total number of events in our tagged sample that are mistags

Produces a complete prediction of process content across jet multiplicity

Process	1jet	2jets	3jets	4jets	5jets
Pre-tag Data	272347	44868	7605	1686	383
Wbb	802.3 \pm 244.6	498.0 \pm 154.5	136.9 \pm 43.3	32.3 \pm 10.5	6.5 \pm 2.5
Wcc	431.4 \pm 135.2	219.6 \pm 69.6	64.3 \pm 20.7	16.8 \pm 5.6	3.6 \pm 1.4
Wc	1002.9 \pm 314.4	260.0 \pm 82.5	48.8 \pm 15.7	8.9 \pm 2.9	1.5 \pm 0.6
Mistags	946.7 \pm 143.6	310.2 \pm 53.9	83.5 \pm 17.2	18.9 \pm 4.8	3.5 \pm 1.6
Non-W	487.9 \pm 146.4	356.4 \pm 106.9	102.2 \pm 30.6	20.9 \pm 17.5	6.4 \pm 6.0
WW	17.7 \pm 2.3	44.1 \pm 5.7	14.0 \pm 1.8	3.5 \pm 0.5	1.0 \pm 0.1
WZ	9.0 \pm 1.0	19.2 \pm 2.2	5.1 \pm 0.6	1.2 \pm 0.1	0.3 \pm 0.0
ZZ	0.7 \pm 0.1	1.9 \pm 0.3	1.0 \pm 0.1	0.3 \pm 0.0	0.1 \pm 0.0
Z+jets	48.7 \pm 6.7	36.3 \pm 4.6	13.6 \pm 1.7	3.3 \pm 0.4	0.7 \pm 0.1
Single Top (s-channel)	11.4 \pm 1.2	42.0 \pm 4.1	13.1 \pm 1.3	2.8 \pm 0.3	0.6 \pm 0.1
Single Top (t-channel)	37.6 \pm 3.3	52.4 \pm 4.6	14.3 \pm 1.2	2.8 \pm 0.2	0.4 \pm 0.0
$t\bar{t}$ (6.7pb)	19.2 \pm 2.7	154.9 \pm 21.6	345.4 \pm 48.0	358.6 \pm 49.7	121.5 \pm 16.8
Total Prediction	3815.5 \pm 720.1	1995.1 \pm 325.3	842.0 \pm 99.1	470.3 \pm 56.5	145.9 \pm 18.5
Observed	3906	1926	813	494	156

CDF Run II Preliminary $\mathcal{L} = 2.7 \text{ fb}^{-1}$

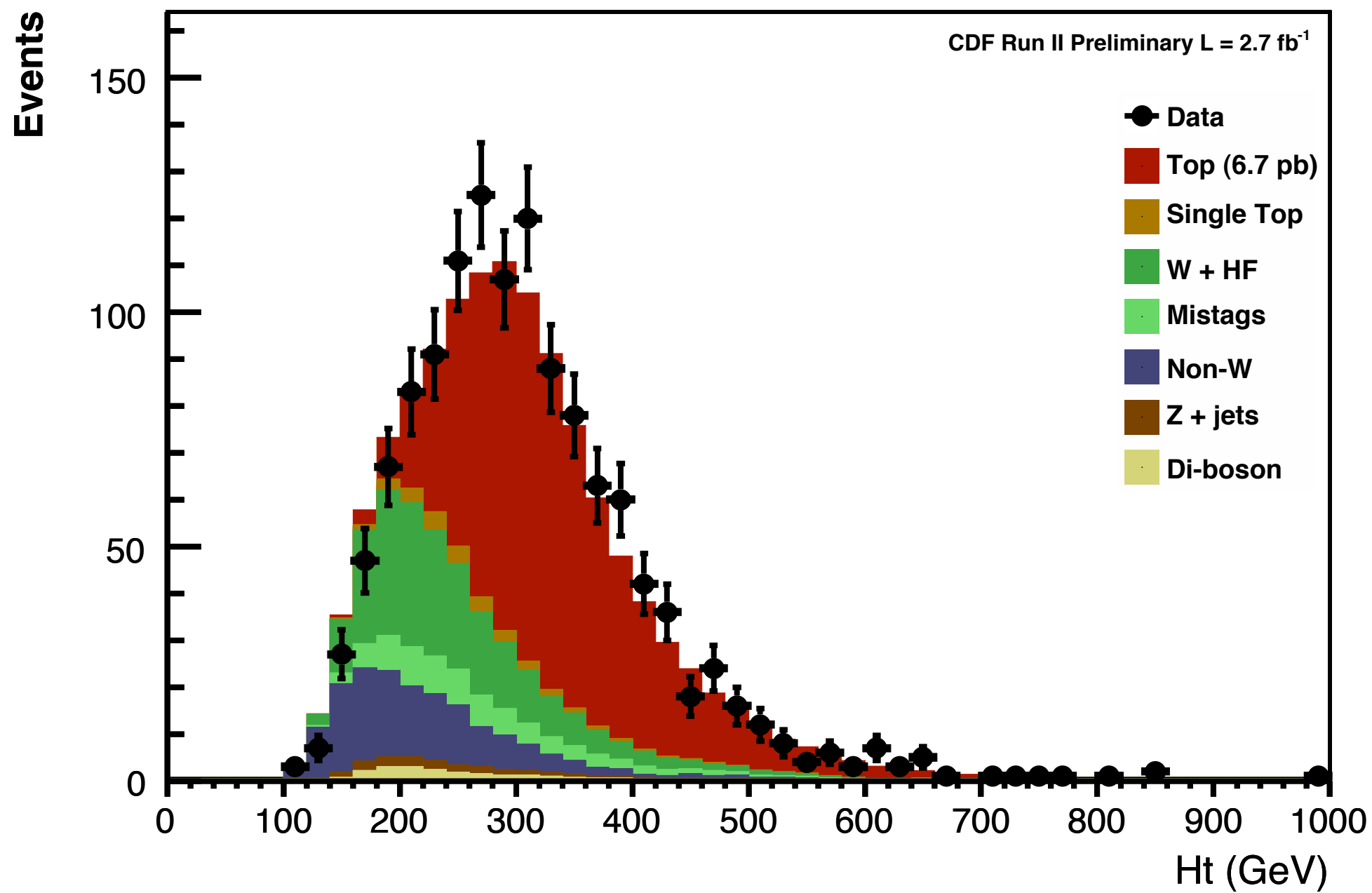


Signal Region

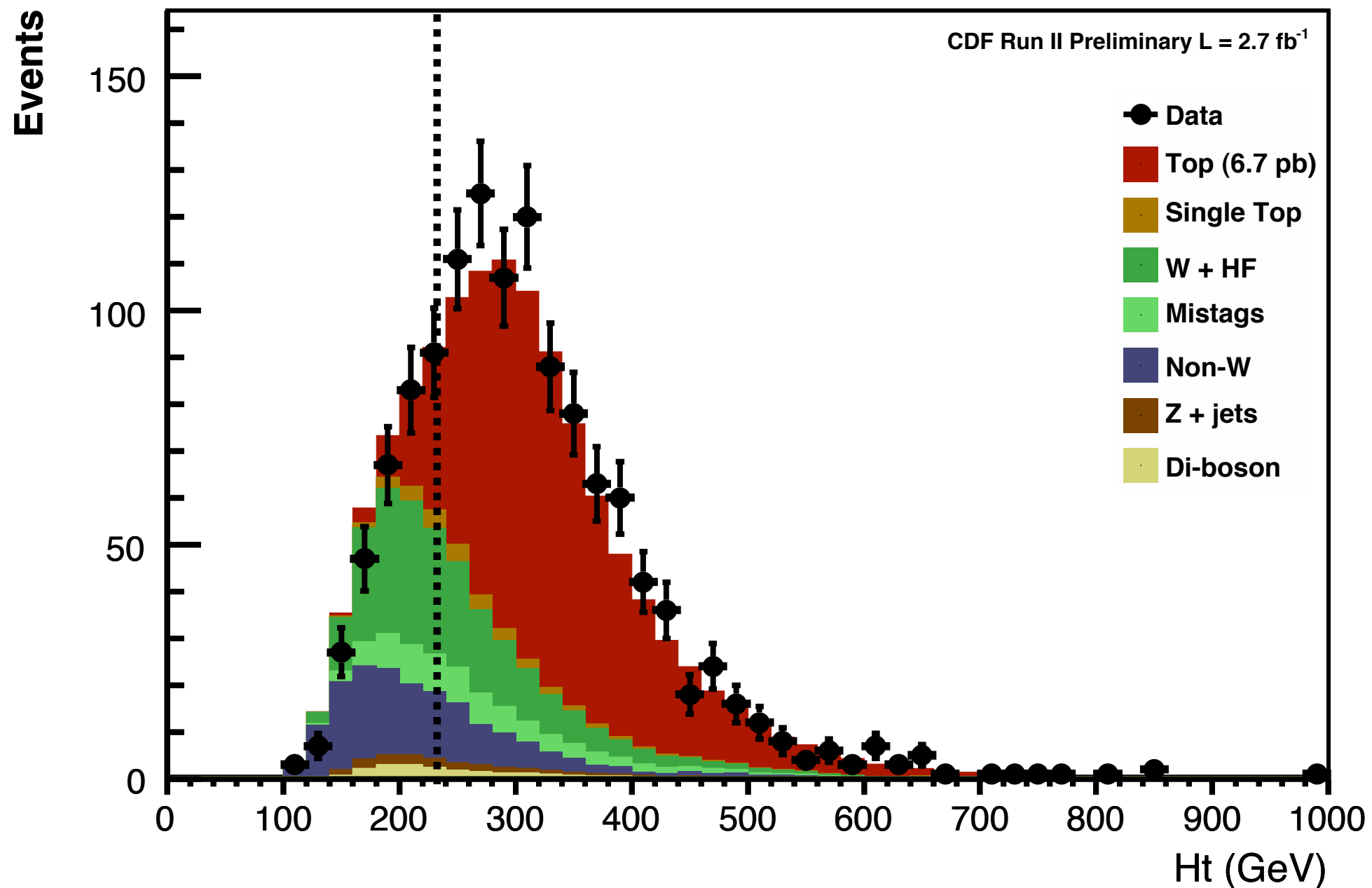
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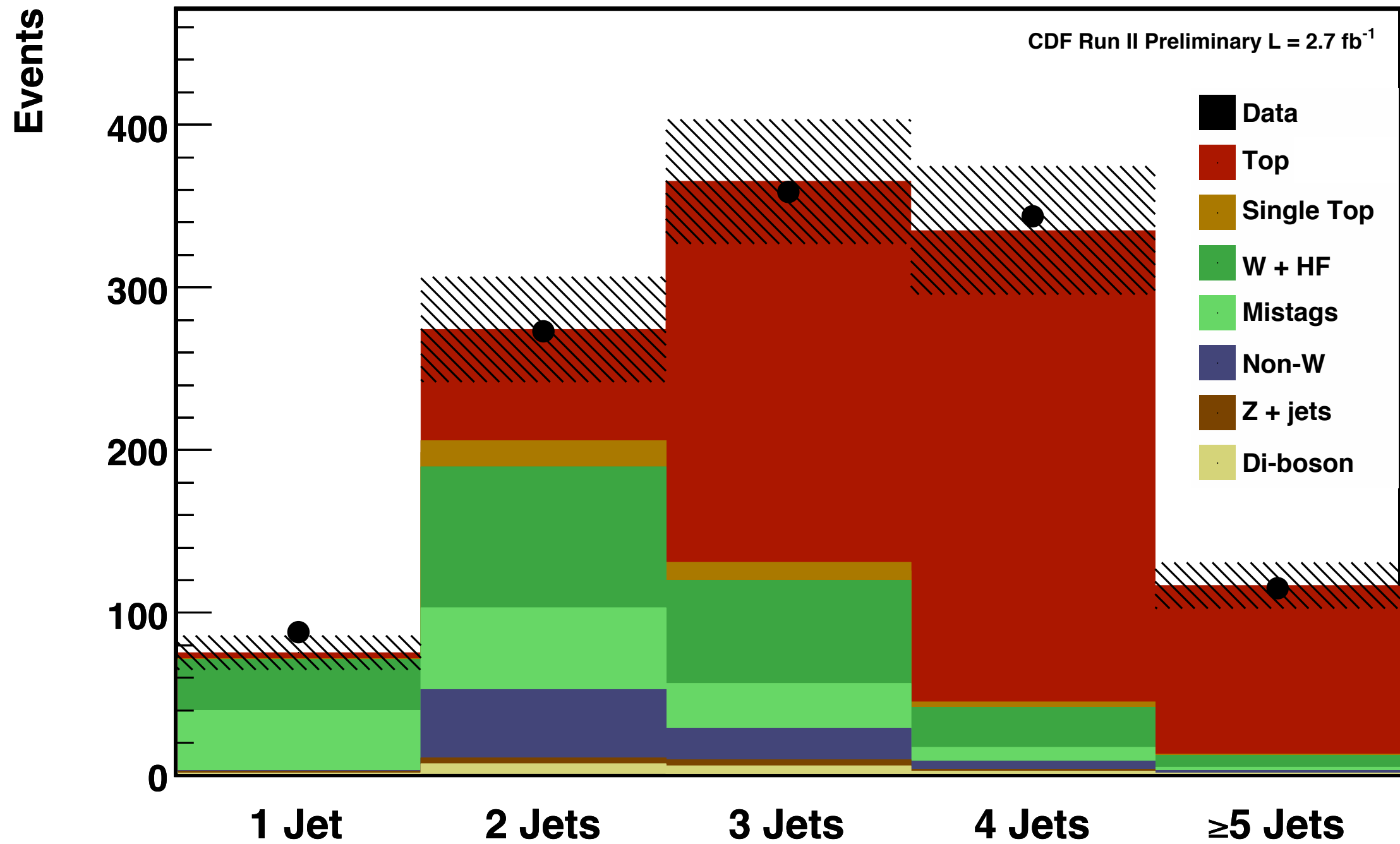
For ≥ 3 Jets S:B \sim 1:1



More Background Reduction



S:B ~ 1:1 → 3:1



Process	1jet	2jets	3jets	4jets	5jets
Pretag Data	2182	2749	1702	885	271
Wbb	16.7 ± 5.1	47.5 ± 14.8	35.4 ± 11.0	13.7 ± 4.9	4.1 ± 1.7
Wcc	7.1 ± 2.3	20.5 ± 6.5	17.4 ± 5.5	7.3 ± 2.6	2.3 ± 0.9
Wc	7.4 ± 2.4	19.0 ± 6.1	10.6 ± 3.4	3.4 ± 1.2	0.9 ± 0.4
Mistags	37.0 ± 4.3	50.3 ± 7.9	27.8 ± 5.0	8.5 ± 3.1	2.1 ± 1.2
Non-W	0.5 ± 1.0	41.9 ± 12.6	19.3 ± 6.3	4.8 ± 4.3	1.7 ± 1.8
Z+Jets	1.2 ± 0.1	3.6 ± 0.4	3.6 ± 0.4	1.5 ± 0.2	0.5 ± 0.1
WW	1.0 ± 0.1	5.3 ± 0.7	4.3 ± 0.5	1.9 ± 0.2	0.7 ± 0.1
WZ	0.3 ± 0.0	1.6 ± 0.2	1.3 ± 0.1	0.5 ± 0.1	0.2 ± 0.0
ZZ	0.0 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.1 ± 0.0	0.0 ± 0.0
Single Top (s-channel)	0.4 ± 0.0	8.7 ± 0.9	5.6 ± 0.5	1.8 ± 0.2	0.5 ± 0.0
Single Top (t-channel)	0.1 ± 0.0	7.3 ± 0.6	5.3 ± 0.4	1.7 ± 0.1	0.3 ± 0.0
$t\bar{t}$	3.6 ± 0.5	68.3 ± 9.0	234.3 ± 30.7	289.9 ± 37.9	103.7 ± 13.6
Total Prediction	75.4 ± 10.6	274.2 ± 32.3	365.1 ± 38.1	335.1 ± 39.5	116.8 ± 14.1
Observed	88	273	359	344	115

CDF Run II Preliminary $\mathcal{L} = 2.7 \text{ fb}^{-1}$

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Wc	7.4 ± 2.4	19.0 ± 6.1	10.6 ± 3.4	3.4 ± 1.2	0.9 ± 0.4
Mistags	37.0 ± 4.3	50.3 ± 7.9	27.8 ± 5.0	8.5 ± 3.1	2.1 ± 1.2
Non-W	0.5 ± 1.0	41.9 ± 12.6	19.3 ± 6.3	4.8 ± 4.3	1.7 ± 1.8
Z+Jets	1.2 ± 0.1	3.6 ± 0.4	3.6 ± 0.4	1.5 ± 0.2	0.5 ± 0.1
WW	1.0 ± 0.1	5.3 ± 0.7	4.3 ± 0.5	1.9 ± 0.2	0.7 ± 0.1
WZ	0.3 ± 0.0	1.6 ± 0.2	1.3 ± 0.1	0.5 ± 0.1	0.2 ± 0.0
ZZ	0.0 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.1 ± 0.0	0.0 ± 0.0
Single Top (s-channel)	0.4 ± 0.0	8.7 ± 0.9	5.6 ± 0.5	1.8 ± 0.2	0.5 ± 0.0
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CDF Run II Preliminary $\mathcal{L} = 2.7 \text{ fb}^{-1}$

The Cross-Section

$$\sigma_{t\bar{t}} = \frac{N_{data} - N_{bkg}}{A \cdot \int \mathcal{L} dt}$$

Acceptance



Integrated Luminosity



The Cross-Section

$$\sigma_{t\bar{t}} = \frac{N_{data} - N_{bkg}(\sigma_{t\bar{t}})}{A \cdot \int \mathcal{L} dt}$$

Acceptance



Integrated Luminosity



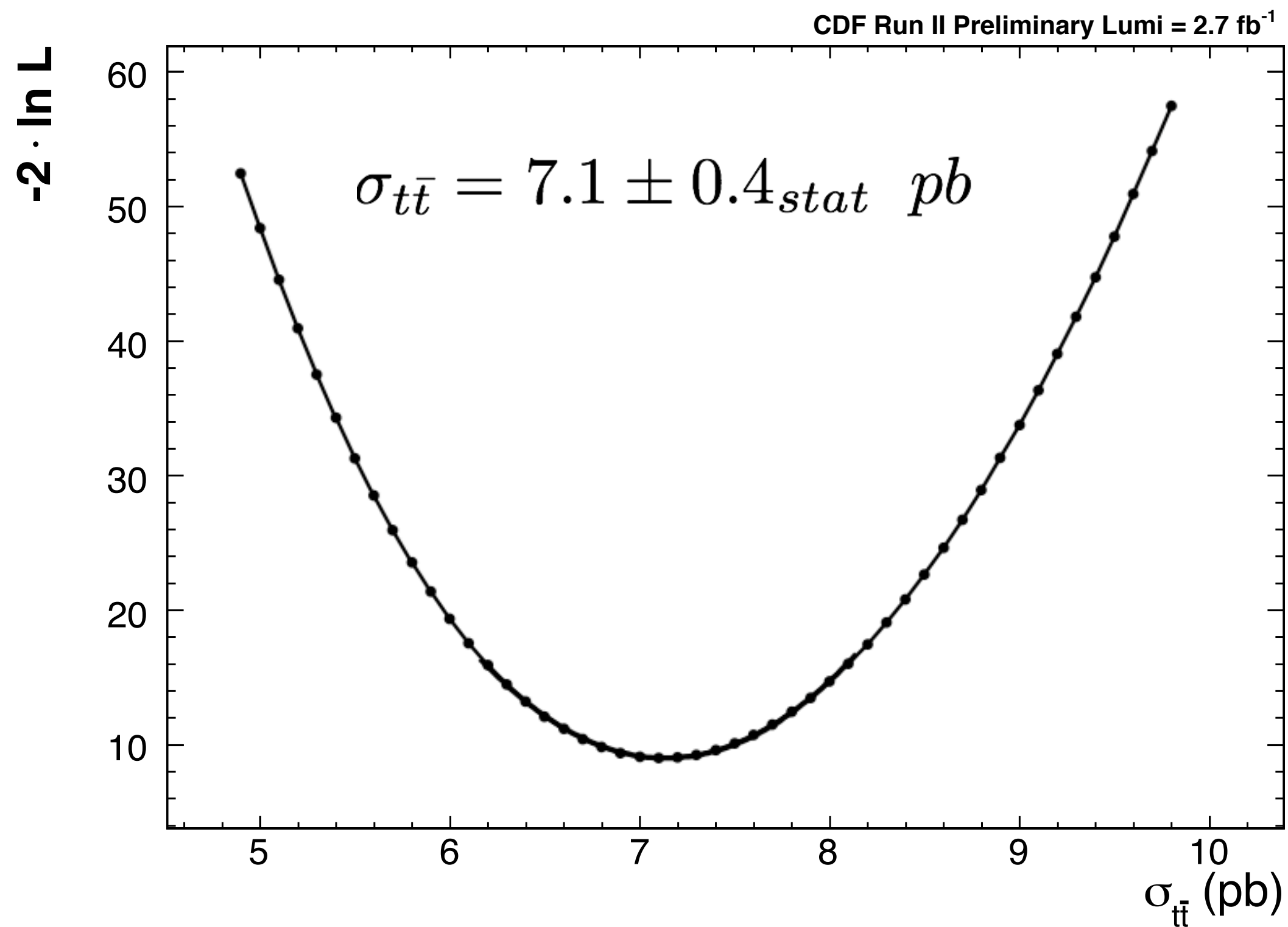
Extracting the X-section

- Because the background estimate is a function of the top cross-section it's not so simple to calculate
- Worse, error propagation basically becomes impossible
- What we can do is construct a Poisson Likelihood from the predicted number of events and the data, evaluate the Likelihood for a range of cross-section values, and extract the minimum value and the statistical uncertainty

$$-2 \cdot \ln L = -2 \cdot (N_{data} \cdot \ln(D \cdot \sigma + B) - \ln(N_{data}!) - (D \cdot \sigma + B))$$

$$D = A \int \mathcal{L} dt = \frac{N_{pred}(\sigma_{t\bar{t}})^{N_{data}} \cdot e^{-N_{pred}(\sigma_{t\bar{t}})}}{N_{data}!}$$

$B = \text{Background estimate at cross-section } \sigma$



Measurement in 2.7 fb⁻¹

$$\sigma_{t\bar{t}} = 7.1 \pm 0.4_{\text{stat}} \pm 0.6_{\text{sys}} \pm 0.4_{\text{lum}} \text{ pb}$$

@ $M_t = 175 \text{ GeV}/c^2$

$$\frac{\Delta\sigma}{\sigma} = 11.6\%$$

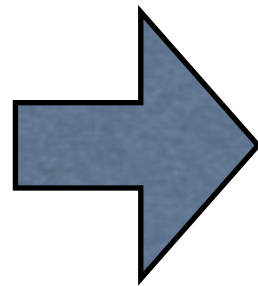
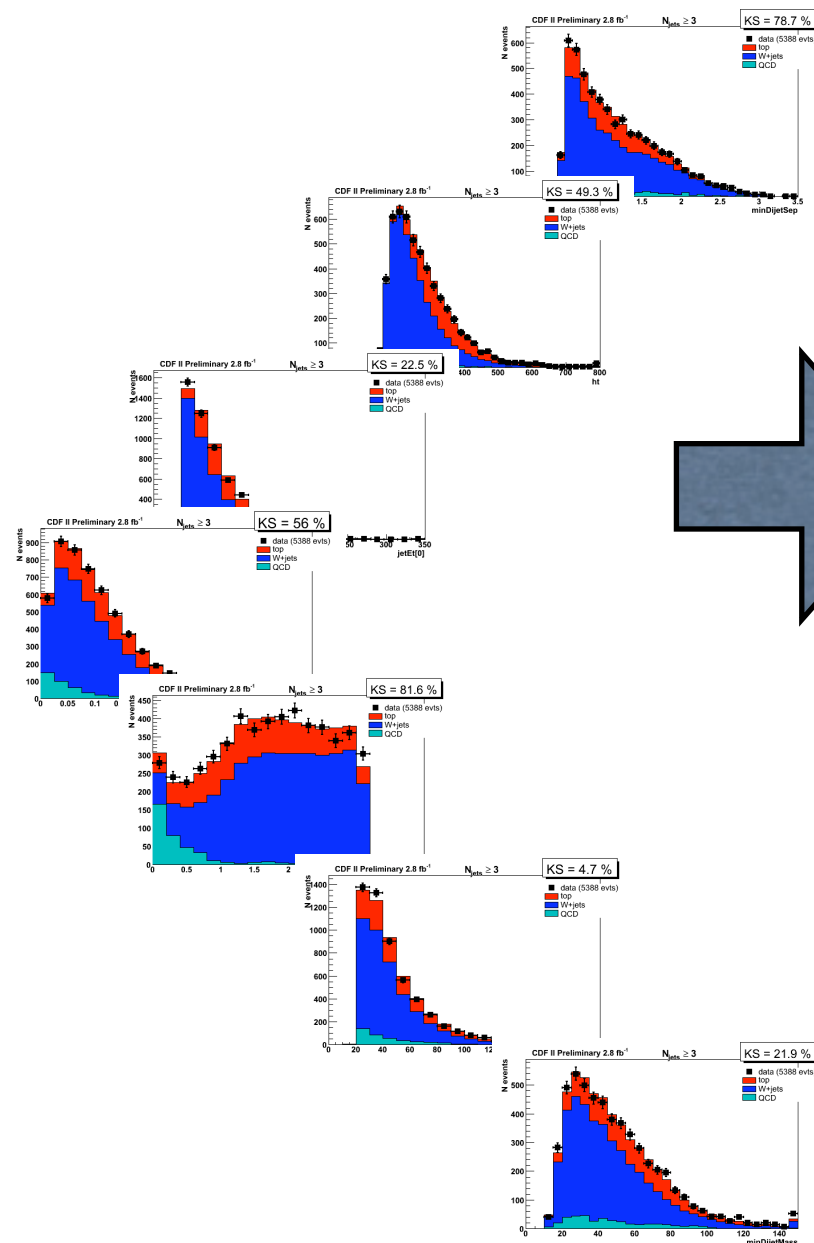
Systematics

SYSTEMATIC	Δ	$\Delta\%$
JET ENERGY SCALE	0.3	4.1
TAGGING	0.4	5.5
MISTAGS	0.2	2.4
HEAVY FLAVOR CORRECTION	0.3	3.8
LUMINOSITY	0.4	6.1
QCD	0.1	0.8
MONTE CARLO GENERATOR	0.2	3.0
INITIAL/FINAL STATE RADIATION	0.1	0.8
LEPTON ID	0.0	0.6
Z0	0.0	0.3
PDF	0.0	0.6
TOTALS	0.8	10.7

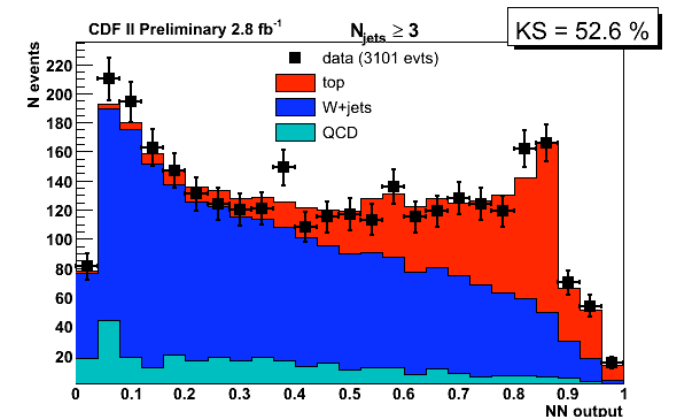
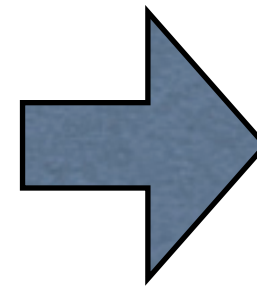
Another Approach

- As opposed to using bottom tagging to reduce backgrounds, use event kinematics to distinguish signal from background
- More model-dependent, but increased statistics and no sensitivity to the last measurements two largest systematics

Topological Measurement



Neural Network



- Feed distributions into Neural Net, trained to distinguish signal from background
- Fit signal and background templates to the data at Neural Net output

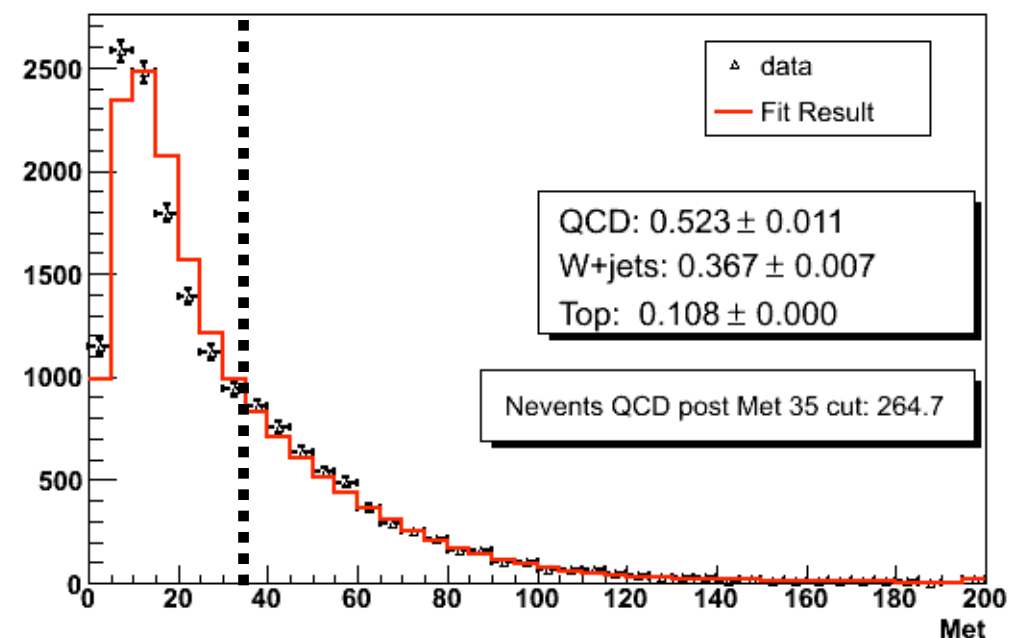
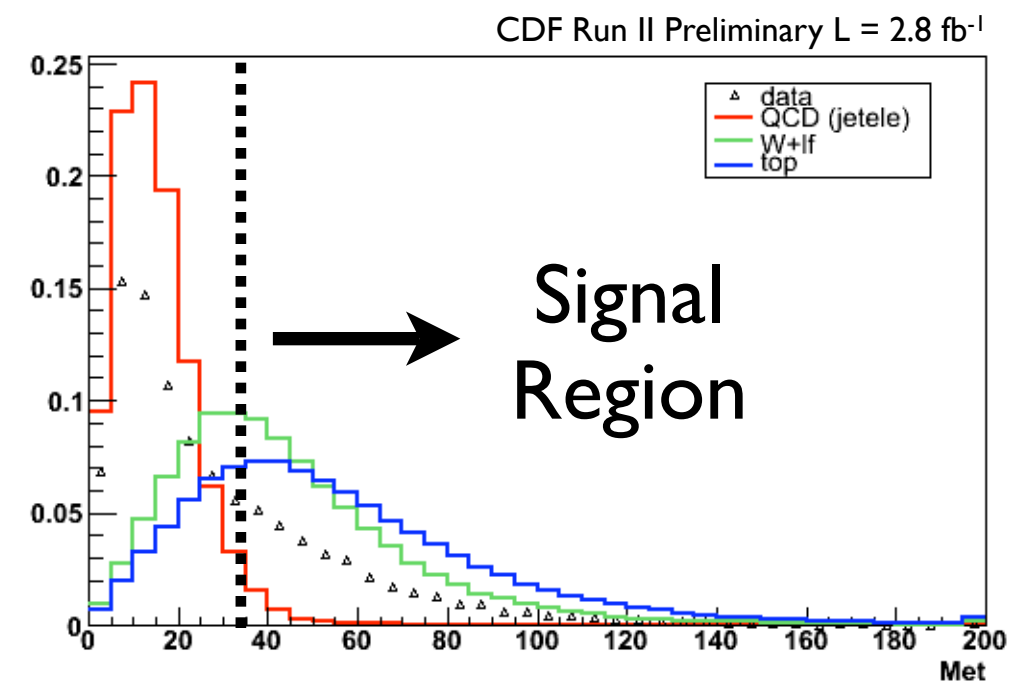
Backgrounds

- Absolutely dominated by QCD and W +Jets
- For simplicity, W +Jets is used to model kinematics of all backgrounds except QCD
- QCD is modeled by data
 - All-jet model where one of the jets is kinematically selected to look like a lepton
 - Electron sample where at least two lepton identification cuts fail

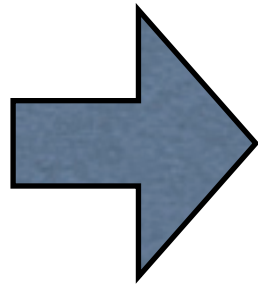
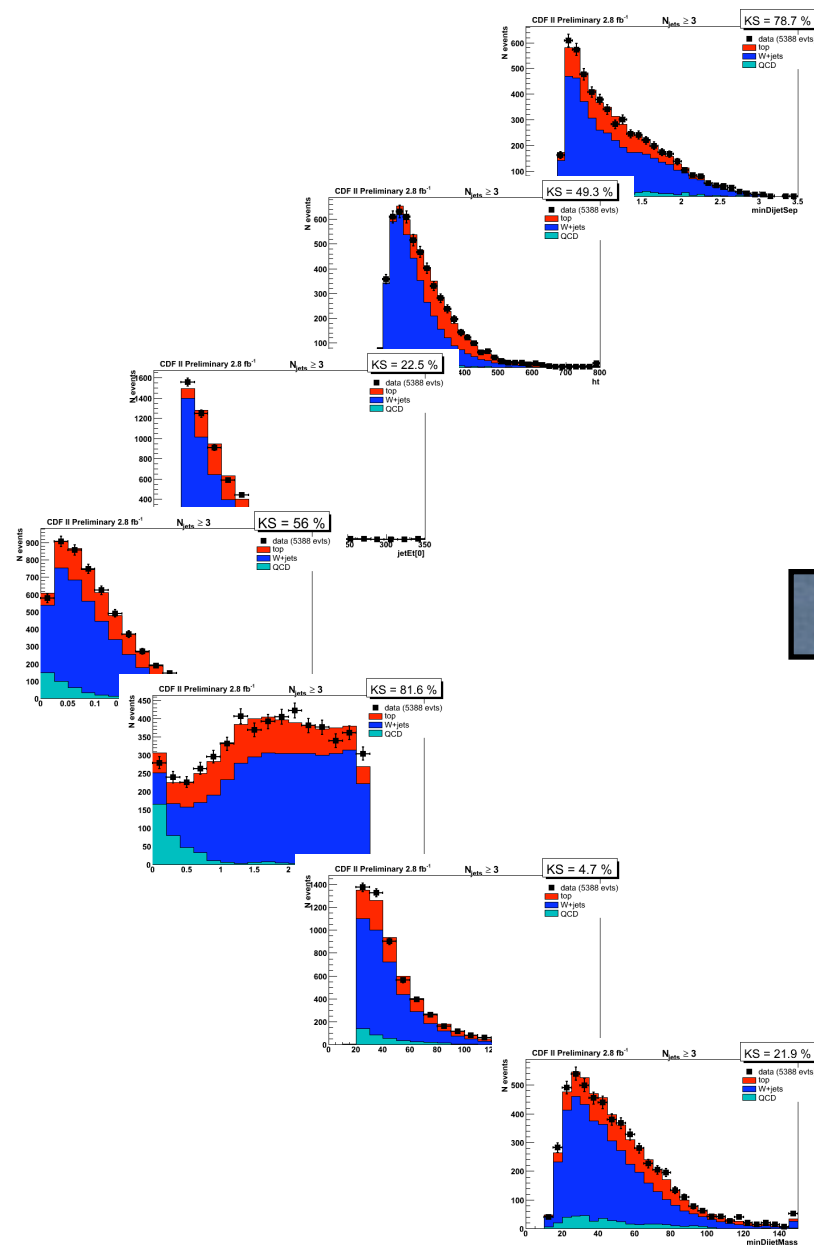
$t\bar{t}$
 $W + Jets$
 QCD
Electroweak

QCD

- As in the previous measurement, QCD is modeled by data
- Could let QCD float in the final fit at neural network output
- Results in a higher systematic
- Use low missing transverse energy region, which is dominated by QCD, to constrain amount of QCD in signal region

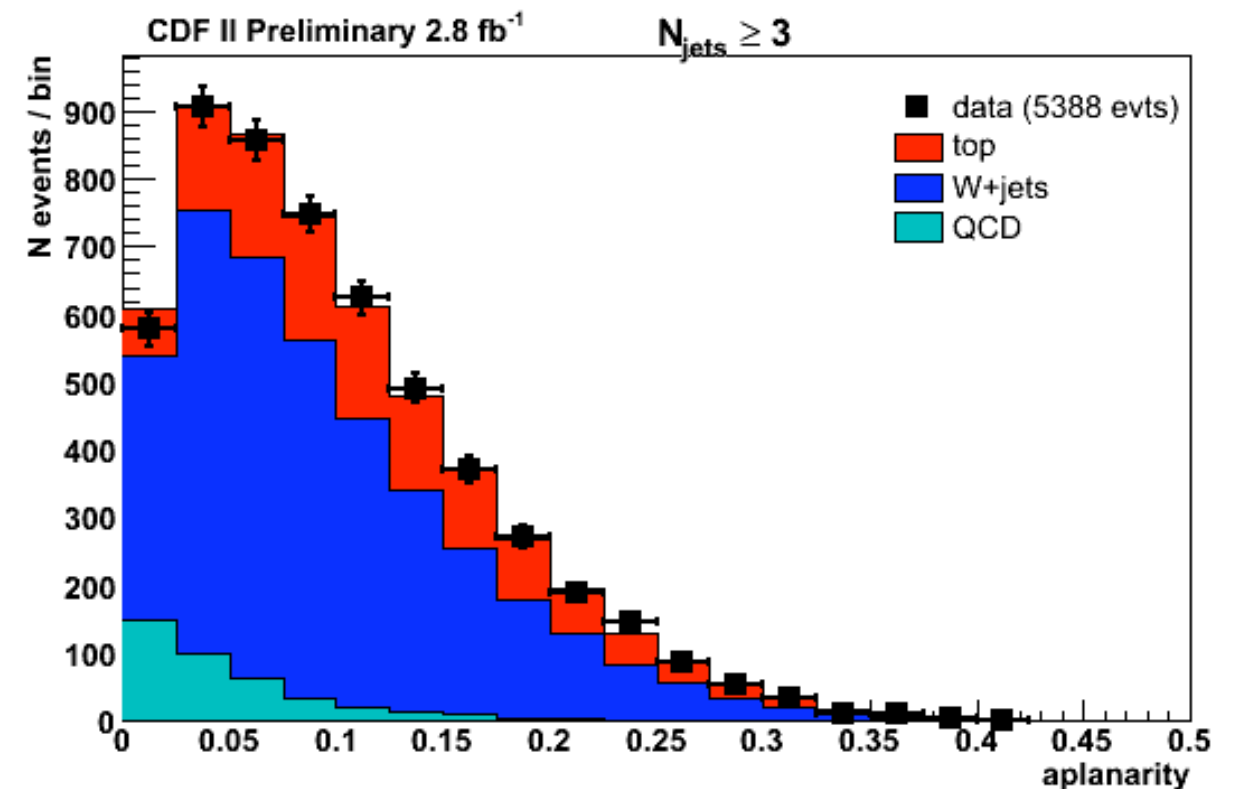
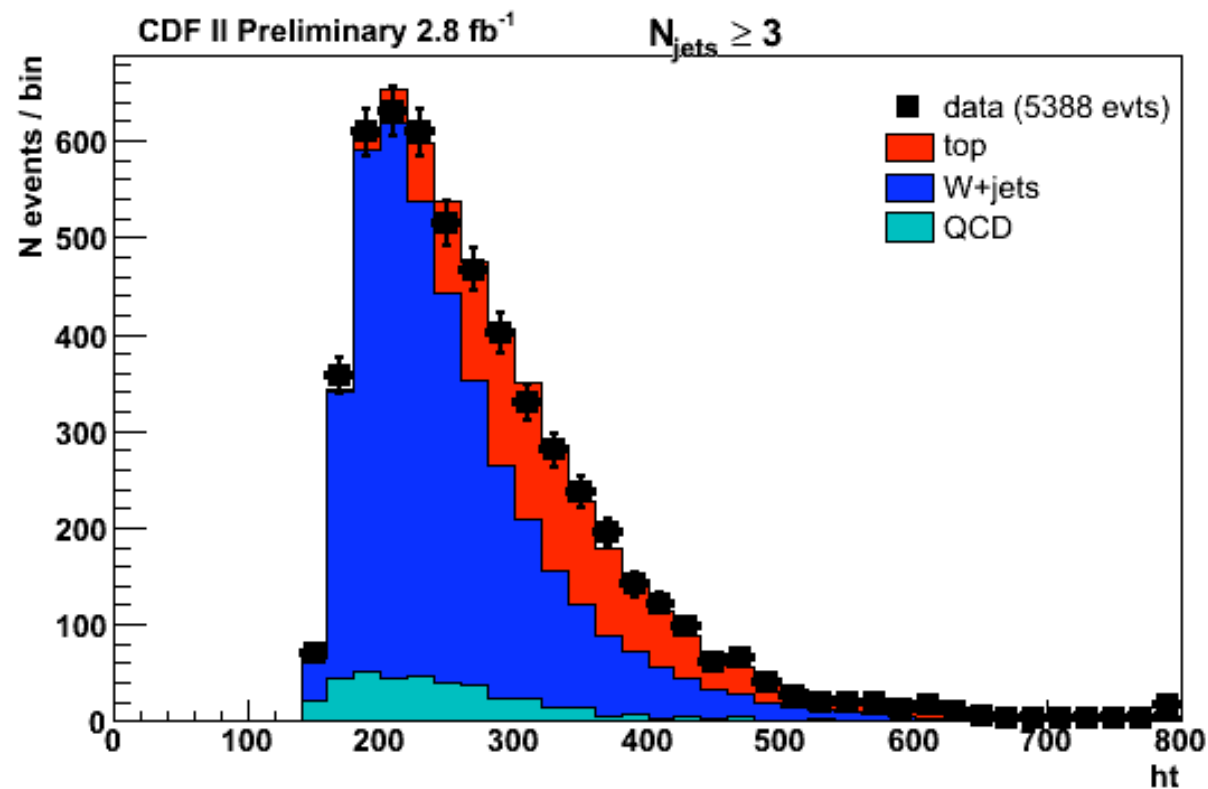


Topological Approach

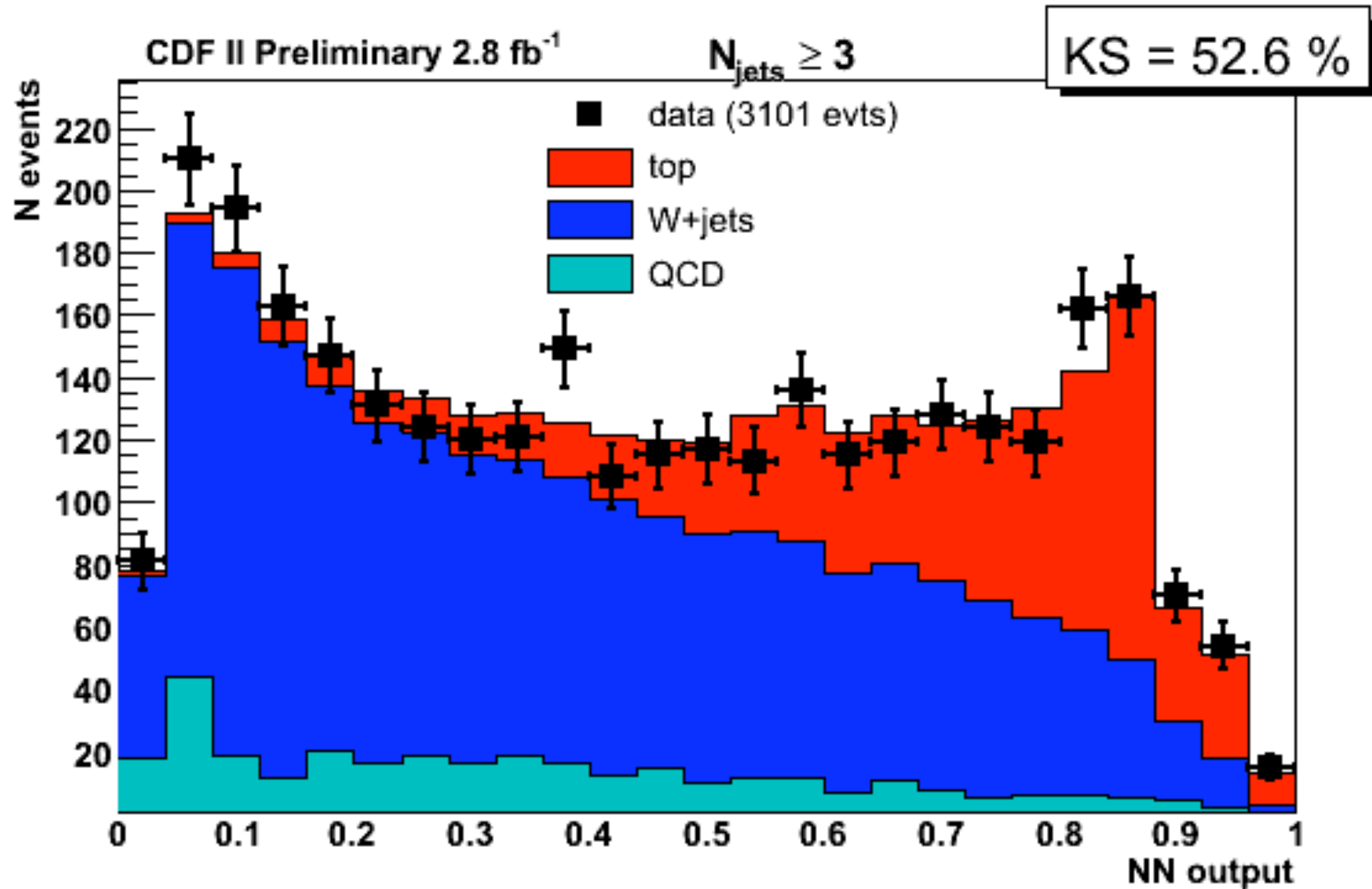


- Total Sum Transverse Energy
- Aplanarity
- Sum P_z / Sum E_t of Jets
- Sum Jet E_t Excluding Two Highest
- Minimum Di-Jet Mass
- Minimum Angle Between Two Jets
- Maximum Angle of a Jet

Kinematic Shapes In



Neural Net Output



Measurement in 2.8 fb⁻¹

$$\sigma_{t\bar{t}} = 7.1 \pm 0.4_{\text{stat}} \pm 0.4_{\text{sys}} \pm 0.4_{\text{lum}} \text{ pb}$$

$$\frac{\Delta\sigma}{\sigma} = 9.4\%$$

Systematics

SYSTEMATIC	Δ	$\Delta\%$
JET ENERGY SCALE	0.2	3.1
Q ²	0.2	2.2
ISR/FSR	0.1	0.8
QCD	0.1	1.6
MONTE CARLO GENERATOR	0.2	2.9
PDF	0.0	0.5
EWK SHAPE MODELING	0.1	1.0
LEPTON ID	0.0	0.6
LUMINOSITY	0.4	5.8
TOTALS	0.4	7.8

Systematics

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Q ²	0.2	2.2
ISR/FSR	0.1	0.8
QCD	0.1	1.6
MONTE CARLO GENERATOR	0.2	2.9
PDF	0.0	0.5
EWK SHAPE MODELING	0.1	1.0
LEPTON ID	0.0	0.6
LUMINOSITY	0.4	5.8
TOTALS	0.4	7.8

Previous measurement
tagging systematic $\sim 5.5\%$

Summary

Dilepton

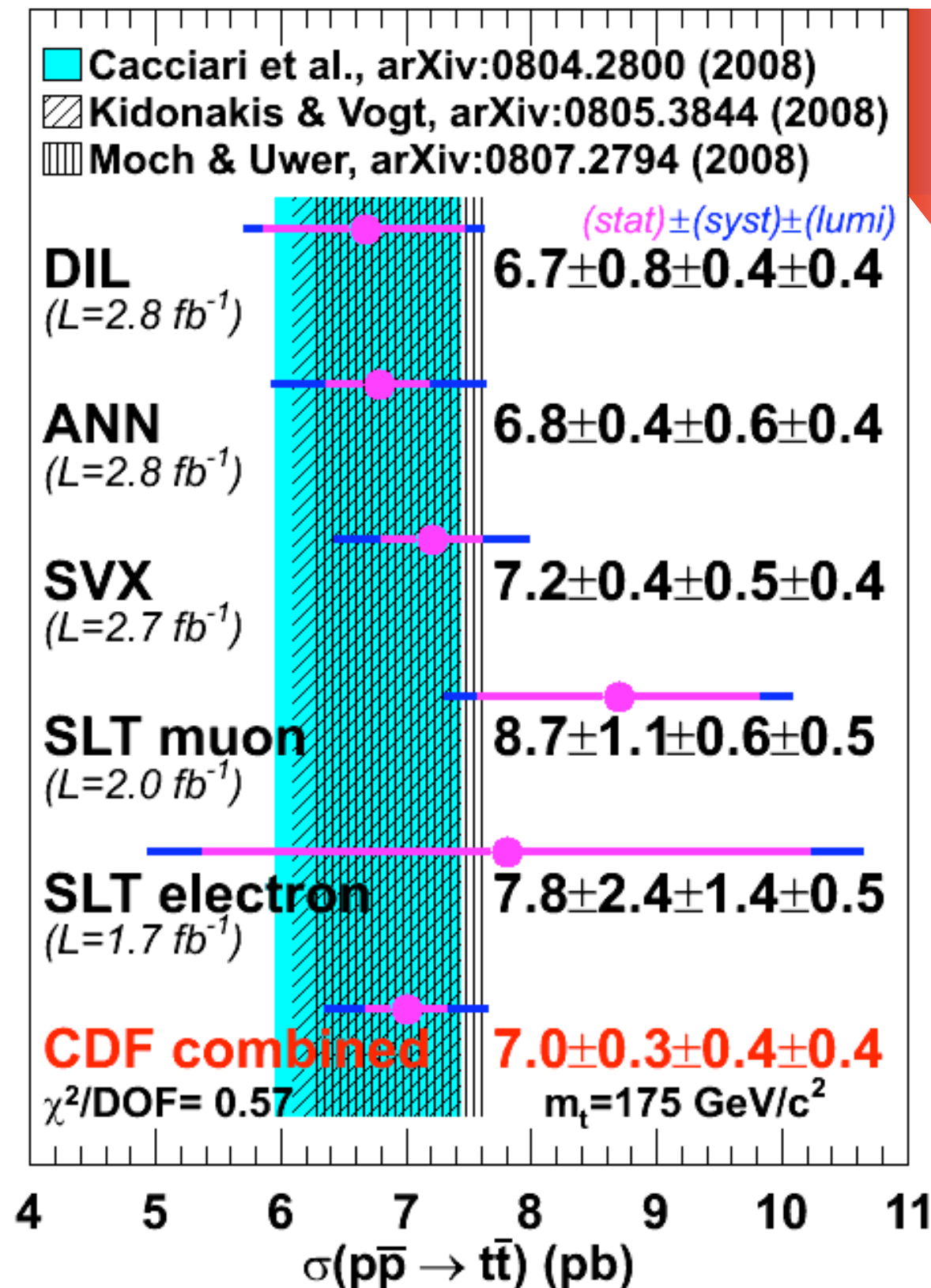
$$\sigma_{t\bar{t}} = 6.7 \pm 0.8_{\text{stat}} \pm 0.4_{\text{sys}} \pm 0.4_{\text{lum}} \text{ pb}$$

Lepton + Jets Tagging

$$\sigma_{t\bar{t}} = 7.1 \pm 0.4_{\text{stat}} \pm 0.6_{\text{sys}} \pm 0.4_{\text{lum}} \text{ pb}$$

Lepton + Jets Neural Net

$$\sigma_{t\bar{t}} = 7.1 \pm 0.4_{\text{stat}} \pm 0.4_{\text{sys}} \pm 0.4_{\text{lum}} \text{ pb}$$

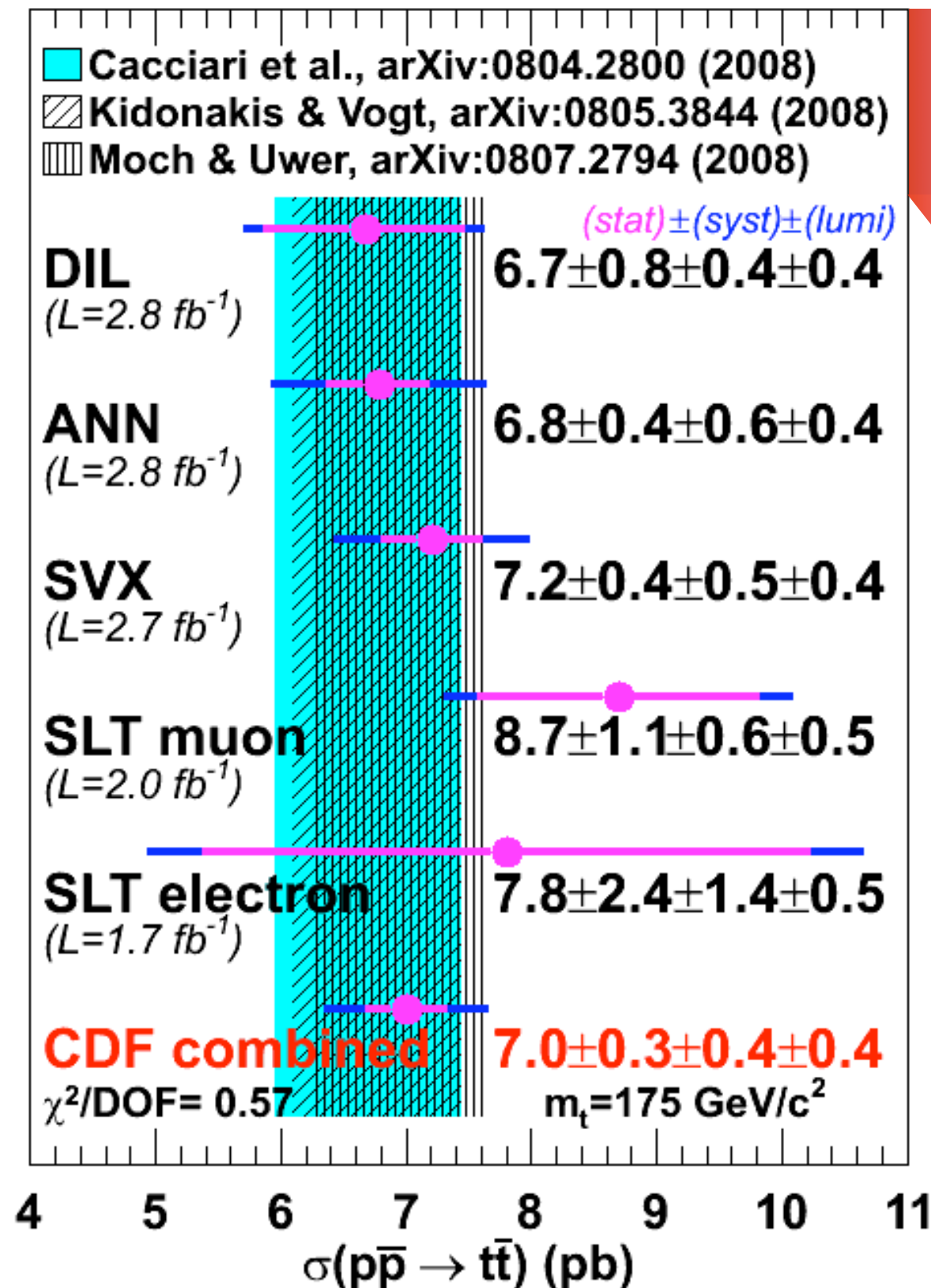


$$\sigma = 6.73^{+0.72}_{-0.63} \text{ pb}$$

$$\sigma = 6.90^{+0.46}_{-0.64} \text{ pb}$$

$$\sigma = 6.73^{+0.71}_{-0.79} \text{ pb}$$

$$\frac{\Delta\sigma}{\sigma} = 9\%$$



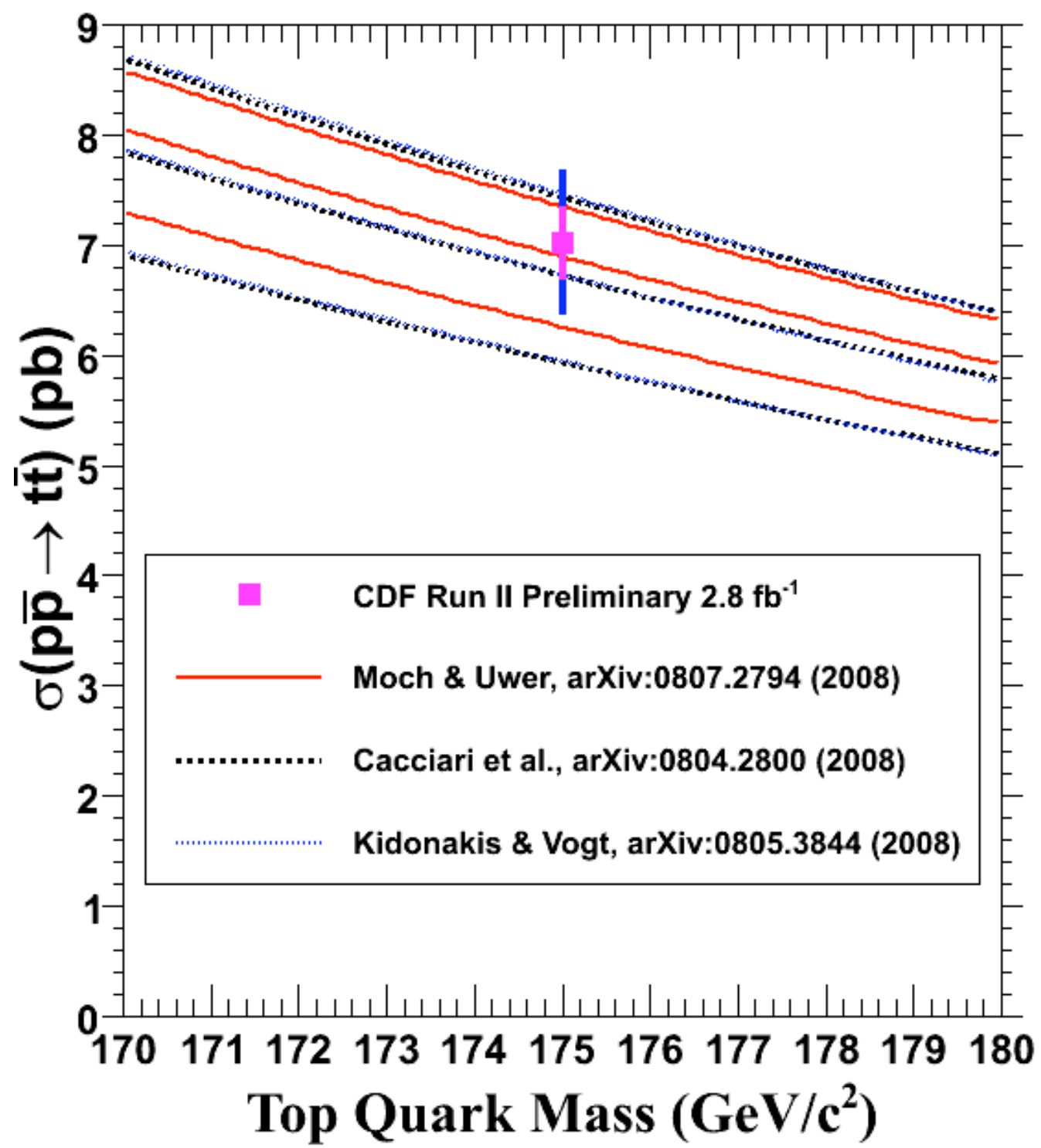
$$\sigma = 6.73^{+0.72}_{-0.63} \text{ pb}$$

$$\sigma = 6.90^{+0.46}_{-0.64} \text{ pb}$$

$$\sigma = 6.73^{+0.71}_{-0.79} \text{ pb}$$

$$\frac{\Delta\sigma}{\sigma} = 8 - 10\%$$

$$\frac{\Delta\sigma}{\sigma} = 9\%$$



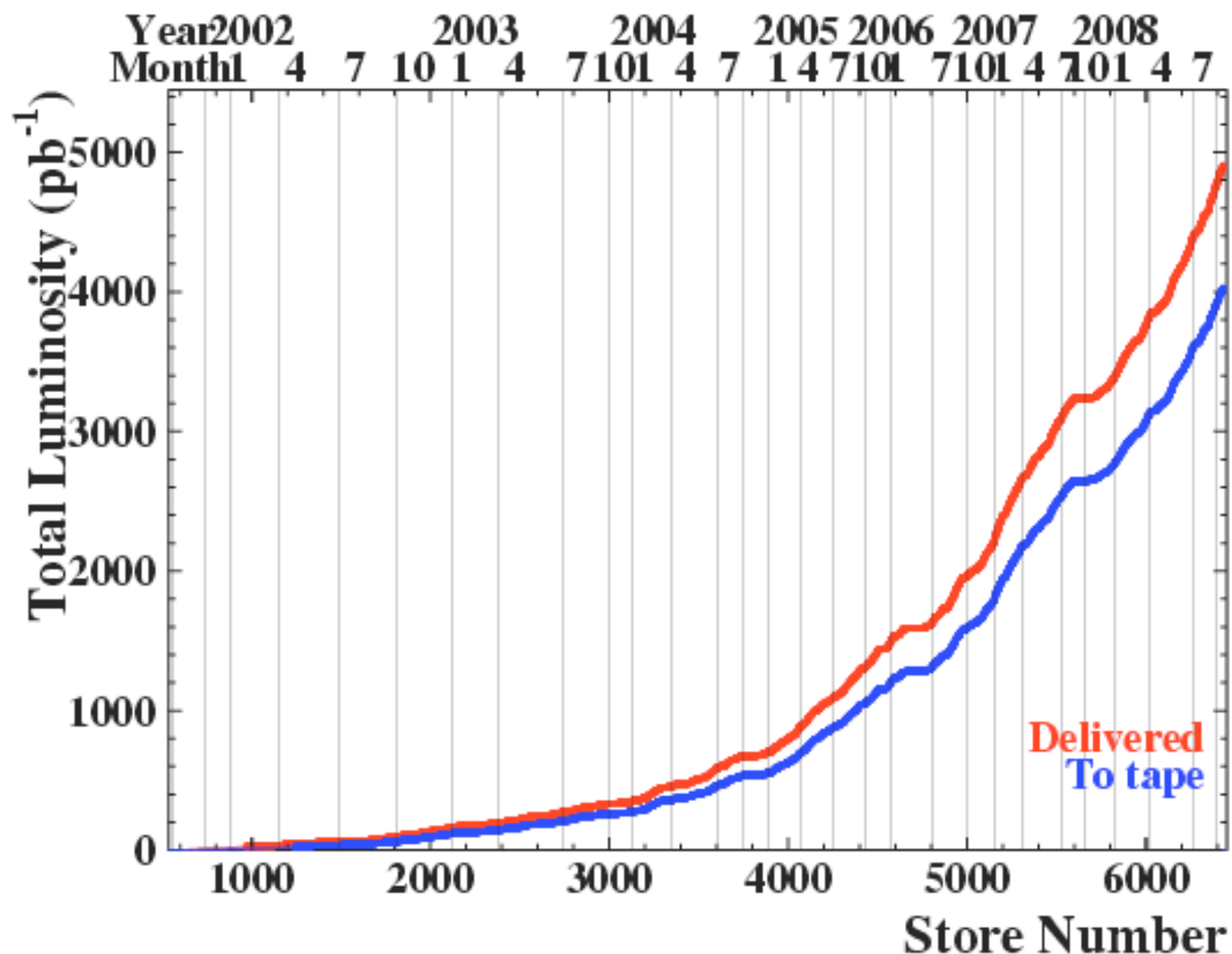
So Does The Standard Model Survive?

Yes, but....

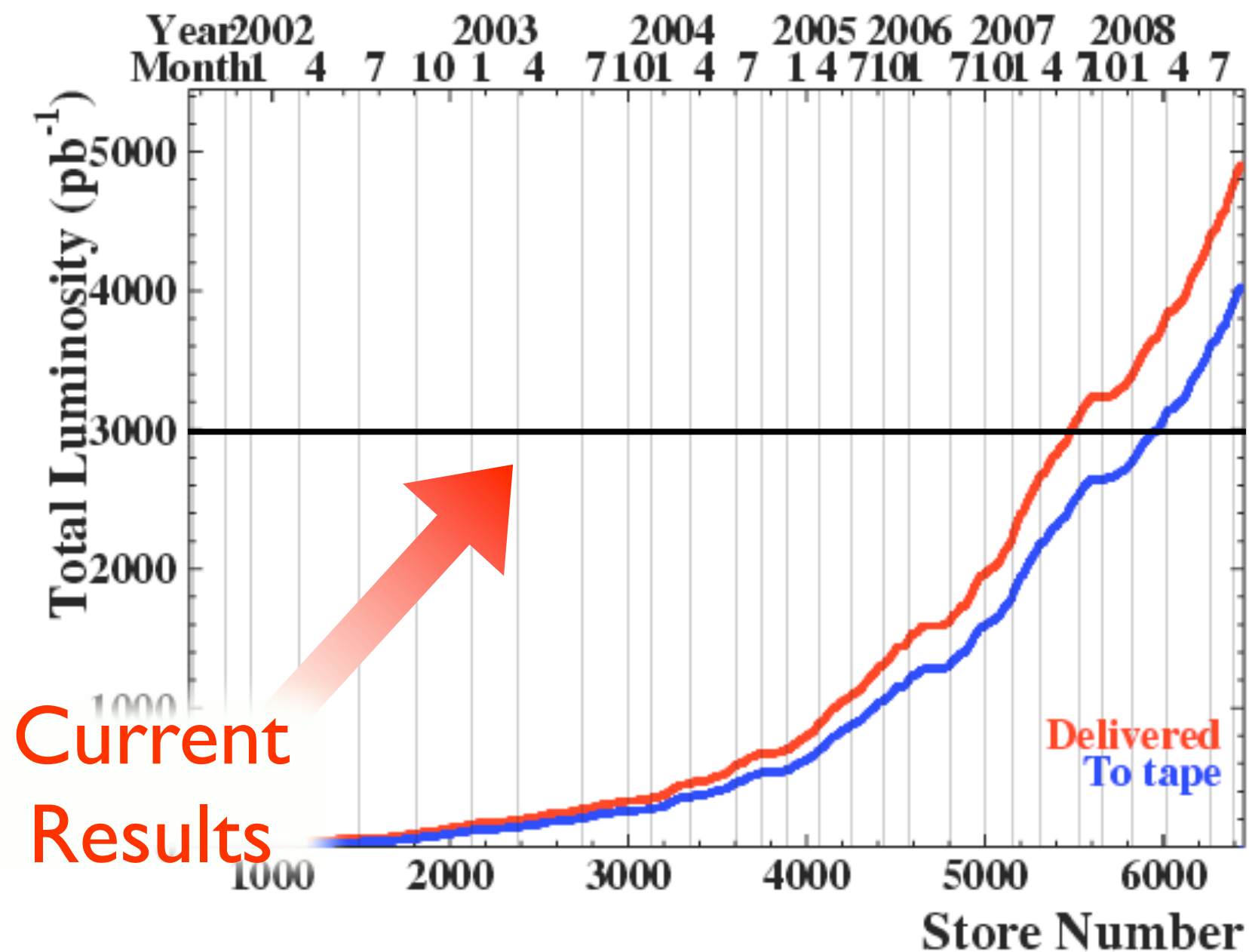
So Does The Standard Model Survive?

- Uncertainty on cross section is still 5-10%, plenty of room for ~ 0.5 -1.0 pb additional production mechanism or anomalous decay
- Somewhat discrepant results still present in top physics - many still too statistically limited
 - t' Search
 - A_{fb}

Does the Tevatron have one last Discovery left?



Does the Tevatron have one last Discovery left?



Does the Tevatron have one last Discovery left?

